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AD A078232

IDA PAPER P-1435

THE EFFECT OF PRICE COMPETITION ON WEAPON SYSTEM ACQUISITION COSTS

George G. Daly
Howard P. Gates
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September 1979

Prepared for

Office of the Under Secretary of Defense Research and Engineering
(Acquisition and Policy)

IDA

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION

79 12 6 131

IDA Log No. HQ 79-21585

The work reported in this document was conducted under Contract No. MDA903 79 C 0202 for the Department of Defense. The publication of this IDA paper does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that agency.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
THE EFFECT OF PRICE COMPETITION ON WEAPON SYSTEM ACQUISITION COSTS.

5. TYPE OF REPORT & PERIOD COVERED
(9) FINAL rept.

6. PERFORMING ORG. REPORT NUMBER
IDA PAPER P-1435

7. AUTHOR(s)
George G. Daly, Howard P. Gates, James A. Schuttinga

8. CONTRACT OR GRANT NUMBER(s)
(15) MDA903-79-C-0202

9. PERFORMING ORGANIZATION NAME AND ADDRESS
INSTITUTE FOR DEFENSE ANALYSES
400 Army-Navy Drive
Arlington, Virginia 22202

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
DARPA Task T-154

11. CONTROLLING OFFICE NAME AND ADDRESS
Deputy Undersecretary of Defense Research & Engineering (Acquisition Policy)
The Pentagon
Washington, DC 20301

(11)

12. REPORT DATE
September 1979

13. NUMBER OF PAGES
249

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
Defense Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

(12) 252

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

(14) IDA-P-1435

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(18) IDA/HQ, SBIE (19) 79-21[illegible] AD-E500 107

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Weapon System Acquisition, Acquisition Policy, Competition, Price Competition, Procurement, Procurement Competition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This paper examines the impact of price competition on weapon systems acquisition. The multidimensional impact of competition on price and non-price aspects of weapon system production and acquisition are discussed. The importance of cost quantity relationships for measuring the effect of competition on price and the theoretical basis of those relationships are reviewed. The problems of and the techniques for accomplishing the transfer of technology associated with competition for production contracts

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

412 219

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are briefly outlined. Previous estimates of savings due to competition are reviewed, and their underlying methodology criticized. It is proposed that the introduction of competition be analyzed as an investment. The eventual reductions in procurement costs must be balanced against the initial costs of introducing competition and establishing a second source. The opportunity cost of government funds should be incorporated by calculating the net discounted present value or the rate of return of introducing competition for the procurement of a particular system. Finally, conclusions and policy recommendations are presented, based upon both empirical analyses and qualitative findings from interviews.

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Contract MDA 903 79 C 0202
Task T-154

ACKNOWLEDGMENTS

The authors wish to thank the personnel of the Armed Services who are responsible for contracting and program management, and who consented to talk with us. Their willingness to discuss the issues and their assistance when locating information for case studies are much appreciated. BG (Army Retired) Samuel Cockerham wrote Appendix E on the procurement of the Light Observation Helicopter. Ms Linda Rosenstock assisted with the calculation of the progress curves and the estimation of the savings due to competition. Evelyn Cole and Deborah Vogel typed the early drafts of this paper; Midge Lanaghan coordinated the typing of the final draft; Ms Eileen Doherty edited and improved the paper considerably. Our thanks to these people for their patience and hard work.

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EXECUTIVE SUMMARY

A. PURPOSE AND STATEMENT

The purpose of this study is to examine the benefits and costs of utilizing price competition during the reprocurement phase of the weapon system acquisition process and to determine:

- When competition should be considered--the required conditions for the introduction of competition;
- How long multiple sources should be maintained if competition is introduced; and
- The changes in policies and practices which would improve the use of competition.

The objectives were addressed by 1) statistical analyses of previous competition, 2) interviews, and 3) case studies.

Three related sequential but overlapping stages precede the reprocurement phase: initial design, development, and initial production.[1] Considerable development effort continues during initial production of a system so transfer of production to a new firm, a potential result of competition, is generally impractical before that phase is completed.

The development and procurement of weapon systems involves a large degree of technological complexity and significant uncertainty. The government assumes a large share of the risk by awarding cost based (rather than fixed price) contracts for initial design and research and development contracts. Moreover, competition in the design phase has traditionally been

[1] For a detailed discussion of this process, see J. Ronald Fox, *Arming America*, Boston, 1974, or M. J. Peck and F. M. Scherer, *The Weapon System Acquisition Process: An Economic Analysis*, Boston, 1962.

dominated by factors other than cost (e.g., design and technological capability of the contractors). As a matter of practice the winner of the design competition is usually awarded the production contracts on a negotiated sole source basis. The resulting absence of price competition in the "downstream" stages of the development process has prompted a number of criticisms among observers of the U.S. weapon systems acquisition process. Among these are:

- The absence of competition in production allows the producer to realize excessive profits, thus leading to excessive costs to the government;
- The absence of competitive pressures and incentives leads to inefficiency in production which result in excessive costs charged to the government under cost-reimbursement contracts;
- The absence of competition in production and the resultant excess profits at this stage lead firms to try to "buy in" at the design phase by subsidizing design proposals. This leads to excessive use of resources during the design stage and inadequate expenditures at the production phase.

B. EVALUATION OF PREVIOUS COMPETITIVE PROCUREMENTS

The introduction of price competition for production is motivated by the expectation of a reduction in price of the system, but nonprice effects may also be significant. Such nonprice effects include technology transfer costs, improvement or deterioration in product quality and reliability, and possible impact on the industrial base (entry or exit of firms).

In evaluating the effects of price competition, two concepts play an important role: learning or progress curves and technology transfer. The concept of the learning curve is central to the task of isolating the change in system price due solely to competition. When competition is introduced other variables (e.g., rate or expected duration of production) relevant to the determination of unit costs often change as well. Hence, great care must be used in interpreting data generated

by previous price competitions. The major costs associated with utilizing price competition are those of transferring the requisite technology between firms. Hence, the relative magnitude of these costs are a major determinant of the viability of price competition.

Three studies of the impact of price competition on previous procurements by the Department of Defense (DoD) were reviewed with special emphasis on a study recently undertaken by the Department of the Army Procurement Research Office (Comptroller). The empirical consequences of the use of competition for system price are quite similar in all the studies: on average the impact of competition is substantial, although the variance is large. A subset of 31 items for which there was sufficient data to allow the estimation of individual progress curves was selected from the three studies for a uniform statistical analysis. For the subset of electronics and communications items gross savings on unit prices, as a result of winner-take-all competitions, averaged 48 percent; for missiles and missile components the average was 28 percent.

However, significant though perhaps unavoidable problems are associated with the studies. These include:

- Poor data and documentation thereof;
- Examples which in many cases reflect neither existing procurements or deliberate strategies and appear in many cases to have been undertaken for goals other than system price reduction;
- Little or no account taken of changes in factors other than system price during competitions;
- Estimated savings expressed in ways which bear no relationship to valid criteria for government decision making, that is, the use of price competition is not viewed as an *investment decision*.

Based on our analyses of these data we have reached several conclusions which express our primary perspectives on the use of price competition:

- The use of price competition is an *investment decision* and should be evaluated accordingly.
- While previous examples of price competition show mixed results they appear, on average, to have represented cost-effective investments of scarce resources. This appears to be particularly true of those examples of competitions whose primary purpose was the reduction of system price.
- Although previous competitions appear to have been good investments, the initial costs incurred in holding them for major weapon systems may not be recouped until three or four years of production are completed. This has an important and seldom noticed implication: While the expanded use of price competition for major systems procurement will reduce DoD costs in the long run, it will almost certainly raise them in the short run. Such competition should be employed as part of a coherent long run strategy and not as an attempt to produce savings in a current period.
- Several characteristics of weapon system procurements appear to be useful indicators of probable success for the use of price competition. In addition to the obvious ones of size and duration of production run, the slope of the sole-source learning curve appears to be a good indicator. The flatter the curve, the more likely are savings to result from competition.

C. INTERVIEWS

Inadequate data and the complexity of the conceptual issues require that the statistical analysis of previous competitions be supplemented by less formal methods of inquiry. These methods include case studies and interviews. The case studies are presented in Appendices B through E. Although not reviewed explicitly in this report, they support the findings of the interviews and the statistical analysis.

The thrust of the interviews was to determine:

- How candidate systems are presently selected;
- The types of problems frequently associated with the introduction of competition;

- System characteristics or other conditions which inhibit the use of competition; and
- Perceptions of the benefits and attitudes toward the desirability of more price-competitive procurements.

Information on those subjects was obtained by discussions with personnel in the material commands responsible for the procurement of weapon systems. The issues covered include:

(1) Program stretchouts

(2) Cost of initiating competition

(3) Risks of delays, defaults, and reduced liability

(4) Technical data problems

(5) Inability to use multi-year contracts

(6) Inadequate incentives

(7) Non-price benefits of competition

(8) Alternatives to pure price competition

(9) Competitive reprocurement and design to cost, design to life-cycle cost, and reliability improvement warranty programs

(10) The need for flexibility.

The major findings of the interviews can be summarized as follows:

- Competitive reprocurement will not be introduced to all systems and components for which it is feasible under present policies and practices. Reasons include adverse incentives and attitudes toward incurring the initial cost and toward the risk and delay for the chance at a future reduction in system price; constraints on funds and personnel required for the initiation of competition; and procurement regulations which tend to restrict choice of competitive techniques.
- There is a tendency to use formally advertised competition more often than appropriate. It is faster, lower cost, and makes more procurements available for small businesses. However, it is risky, especially when the specifications are not firm and the technical data package is inadequate. Once an exception to formally advertised competition is obtained for a particular procurement, other methods of initiating competition are not routinely considered.

- Early planning can reduce costs and delays required to effect transfer of technology and can increase the actual production volume subject to competition.
- Nonprice aspects of competition are significant and may be the deciding factor for or against the introduction of competition. Inadequate technical performance of the original producer, fear of reduced reliability or delivery delays, the impact on the industrial base, and the impact on logistics and maintenance costs have all been deciding factors.
- Production to form-fit-and-function and performance specifications may ease the burden of technology transfer and be an attractive alternative to pure price competition.

D. IMPLEMENTATION OF COMPETITION

Any system for which competition is contemplated should be subjected to an analysis of the impact on net savings and the impact on less easily quantifiable nonprice aspects such as reliability and performance, potential for defaults and delays, the impact on logistics and maintenance costs and the impact on the industrial base. That requires estimation of the annual net change in costs including the net increase in costs required to establish a second source as well as the eventual savings on competitively awarded contracts.

The diversity of characteristics surrounding the procurement of each system defy simple formulation of the decision to introduce competition. However, the review of previous competitive procurements does suggest the information required, where it may be found and reasonable values for some of the underlying parameters. For example, estimates of the cost of introducing competition may be based on previously negotiated options to acquire a technical data package, rights in data, and direct technical assistance from the original developer, and on the initial production and testing costs incurred by the first source (but not the costs of developing the system).

The judgment and experience of personnel in the material commands of the Armed Services are required to determine whether and how to introduce competition for reprocurement, but the Office of the Secretary of Defense (OSD) may wish to specify some of the parameters which underlie the analysis. By so doing the OSD accepts more of the responsibility for the risks associated with the introduction of competition and provides a basis for more uniformity in the analysis of different systems. The data which the OSD may wish to specify include:

(1) Total future requirements of all Services and estimated foreign military sales, and the projected cost of sole-source production of those requirements;

(2) Expected gross reduction in post competition prices--conservative figures are:

a. Ten percent for split awards,

b. Twenty percent for winner-take-all competitions;

(3) How soon production by the second source can be initiated; and

(4) The volume of production required by the second source to gain parity in production costs with the initial source--based on past experience, thirty percent is a conservative figure.

The annual net changes in costs as a result of the introduction of competition should be summarized by calculating the net present discounted value (NPDV) or the internal rate of return. Both of these methods reflect the pattern of annual net savings over time and opportunity cost of government funds, and they are preferable to a break-even analysis which simply sums the annual figures without discounting.

There are three equivalent financial criteria for the introduction of competition. Introduce competition if

- The NPDV of all annual changes in costs calculated with the opportunity cost of government funds as the discount rate is greater than zero;
- The estimated rate of return is greater than the opportunity cost of funds; or

- The discounted value of the post competition gross savings is greater than the estimated start-up costs.

The last criterion may be useful for communication with the material commands as OSD may find it relatively easier to estimate post competition gross savings in price and to depend on the material commands for estimates of start-up costs.

Three different situations identify a particular weapon system or component as a prime candidate for the introduction of competition.

(1) The expected reduction in production costs outweighs the costs of introducing competition and any adverse impact on non-price aspects.

(2) Difficulties with the present contractor are being experienced and substantial volume is left to produce.

(3) Industrial (mobilization) base expansion or maintenance is desired.

Maximum benefits are obtained when as much of the procurement volume is submitted to competitive award as possible. This may be achieved by repeated, formally advertised competition for annual contracts; winner-take-all competition for a multi-year contract; or maintenance of multiple sources for annual split-award competition where the winner receives the largest share of the annual contract. It should be noted that significant savings can be realized from split-award competition. Because of the difficulty in carrying out the first two methods, split-award competition may be the most applicable method for maintaining competitive pressure on annual procurement requirements.

Finally, the following recommendations are advanced to encourage the use of competition when it is economically desirable, by reducing artificial impediments.

As soon as possible:

- Make a firm commitment to the volume of future system requirements;

- Analyze the impact of the introduction of competition, using the methodolcgy developed in this study; and
- Acquire the TDP, rights in data, and technical assistance when required for the introduction of competition.

Make provisions for:

- Funds and personnel required for the implementation of competition;
- Multi-year commitment of funds; and
- Concurrent procurement of the same system or subcomponent from more than one source and at different prices.

Chapter I

INTRODUCTION

The purpose of this study is to examine the benefits and costs of utilizing price competition in the procurement phase of the weapon systems acquisition process and to discern and analyze those factors which determine the magnitude of those benefits and costs. Included in the possible strategies for utilizing price competition are the use of competitive bidding for procurement contracts (commonly known as "breakout"), and other policies such as directed licensing, award splitting, second-sourcing and the efficient contractual procedures required by these techniques.

The outputs of this study include:

- A description of the elements of the weapon systems acquisition process which are of special importance to understanding the role of price competition in that process;
- A categorization of the potential benefits and costs which can arise from the use of price competition;
- Use of both statistical and case study methods to review previous estimates of the magnitudes and benefits of costs which result from the actual introduction of price competition for the reprocurement of systems;
- The development of criteria for use by decision-makers in determining the circumstances under which and the techniques by which price competition is likely to prove cost-effective.

A. THE NATURE OF THE PROBLEM

The weapon systems acquisition process is commonly subdivided into four related sequential but overlapping states: initial design, development, initial production, and reprocurement. The last two stages are those during which actual production takes place; the first two are the research and development phases.[1] As might be expected in a process characterized by technologically related stages, major weapon systems manufacturers are vertically integrated and thus are active in each of these stages.

Historically, for major systems the acquisition policy of the Department of Defense has emphasized competition only at the initial phase of the acquisition process. The winner of this competition then proceeds on an exclusive basis through the remaining stages of the sequential process. Moreover, competition in the design phase has traditionally been dominated by factors other than cost (e.g., technological superiority). Typically, the firm which wins the initial design competition has a virtual monopoly (subject, of course, to competition from other systems) over subsequent phases of the process. The prominence of non-price competitive acquisition policies is indicated by Table 1 below which shows, for selected years, the proportions of contract types used for major DoD acquisitions.

The resulting absence of price competition in the "downstream" stages of the development process has prompted a number of criticisms among observers of the U.S. weapon systems acquisition process. Among these are:

- The absence of competition in production allows the producer to realize excessive profits, thus leading to excessive costs to the government;

[1]For a detailed discussion of this process, see J. Ronald Fox, *Arming America*, Boston, 1974, or M. J. Peck and F. M. Scherer, *The Weapon System Acquisition Process: An Economic Analysis*, Boston, 1962.

Table 1. COMPETITION IN MILITARY PROCUREMENT

Type of Competition	Net Value in Thousands			
	Oct 76 - Mar 77		Oct 77 - Mar 78	
	Amount	%	Amount	%
Competitive (Sub-Total)	9,527,348	37.5	10,594,319	35.9
Formally Advertised	1,681,276	6.5	1,805,574	6.1
Small Business & Labor Surplus Area Set-Asides	1,057,237	4.5	1,304,690	4.4
Other Price Competition	3,141,077	12.4	3,904,442	13.3
Design or Technical Competition	1,637,758	14.5	3,579,613	12.1
Non-Competitive (Sub-Total)	15,863,174	62.5	18,882,007	64.1
Follow-On After Price or Design Competition	4,821,489	19.0	5,191,564	17.6
Other One-Source Solicitations	11,041,685	43.5	13,690,443	46.5
TOTAL, EXCEPT INTRAGOVERNMENTAL	25,390,522	100.0	29,476,326	100.0
INTRAGOVERNMENTAL	2,853,349		3,037,040	
TOTAL	$28,245,871		$32,513,466	

Source: Department of Defense, OSD, "Military Prime Contract Awards," October 1977-March 1978.

- The absence of competitive pressures and incentives leads to inefficiency in production which results in excessive costs charged to the government under cost-reimbursement contracts;
- The absence of competition in production and the resultant excess profits at this stage lead firms to try to "buy in" at the design phase by subsidizing design proposals. This leads to excessive use of resources during the design stage and inadequate expenditures at the production stage.

For these and perhaps other reasons, critics of the traditional weapon systems acquisition process have frequently argued in favor of greater use of price competition in allocating production contracts among weapon systems producers. As attractive as such a policy alternative may appear, formulating it in an

operational manner is not simple, because the decision to initiate competition involves the commitment of resources to the acquisition process. These costs include:

- The transactional costs to the government of "competing" a system, i.e., the cost incurred by the government in requesting and evaluating alternative proposals and contractors in preparing them; the costs of certifying alternative suppliers and underwriting the learning quantities, etc.;
- Added costs of production which might arise if two or more firms actually engage in production, e.g., the inability to fully exploit all economies of scale;
- The costs of acquiring access to technical data and the costs of transferring technology;
- Non-monetary costs associated with multiple producers and/or competitive negotiations, e.g., interchangeability problems and related logistics costs, quality control problems, time delays.

Thus, from the government's point of view, the decision to initiate price competition during reprocurement is, in effect, a decision to incur current costs in the hope of achieving future benefits, primarily in the form of reduced system price. As with any other investment decision, it would be prudent for DoD to invest in the competitive process only when the benefits of doing so outweigh the costs.

Both the benefits and costs of utilizing competition are likely to vary systematically with a number of variables. As a result, the expected payoff from utilizing competition may be both predictable and quantifiable, at least in approximate terms. If this is so, criteria can be provided to DoD decision-makers that should assist them in determining when to initiate competition and in estimating the net benefits of doing so. The formulation of such criteria is the primary objective of this study.

B. THE ORGANIZATION OF THE STUDY

The study consists of several related discussions. The following chapter describes a number of characteristics of weapon systems markets and the weapon systems acquisition process which are of particular importance to the issue of costs/benefits of price competition. Chapter III both categorizes and analyzes the sources of those benefits and costs. Chapter IV describes in some detail the two central issues involved in analyzing price competition in the weapon systems acquisition process--cost-quantity relationships and technology transfer. Chapter V examines methods for implementing price competition. Chapter VI presents a review of several earlier studies of price competition. Chapter VII proposes a methodology for examining the cost-effectiveness of using a price-competitive acquisition process; Chapter VIII examines the structure of this process in greater detail. The final two chapters present, respectively, our conclusions and recommendations for changes in policy.

Chapter II

CENTRAL CHARACTERISTICS OF THE WEAPON SYSTEMS ACQUISITION PROCESS

A. PERVASIVE UNCERTAINTY

The weapon systems acquisition process is characterized by substantial uncertainties of two basic types: *internal* and *external* [Peck and Scherer]. *Internal* uncertainties are due to unforeseen technical difficulties in the development and production of the system. These uncertainties result from the innate complexity of coordinating the various subcomponents of the system, which previously have not been used together, and because the development of a new system often substantially expands the frontiers of technology. *External* uncertainties are not directly related to the technical aspects of the system but may affect the outcome anyway. Changes in the external environment, such as technology or anticipated enemy capabilities and plans, can change our own defense policies which, in turn, may drastically modify or even terminate a weapon system program through no shortcoming of the developer-producer.

The magnitude and diversity of uncertainties, with their associated financial risks and the large expenditures required, simply preclude private investment in the usual manner. In an effort to shift some of the risk away from firms and to itself, the government usually offers some form of cost-reimbursement contract for research and development. A significant amount of government-furnished equipment is often supplied to the contractor, thus reducing the magnitude of the required private investment. Obviously, these and related aspects of the weapon

systems acquisition process reduce the role played by price competition. Complex systems evolving to meet changing needs and requirements built under cost-reimbursement contracts clearly inhibit the use of price competition.

B. TECHNOLOGICAL COMPLEXITY

A related issue concerns the technological complexity of major weapon systems which, as noted, contributes to the uncertainty associated with both the development and production processes. The fact that requirements and products are changing rapidly means that the role of price competition is greatly restricted since the physical and technical characteristics of the product are not well defined. This, in turn, means that some criterion *other than price* must be used in order to assign contracts. The method, of course, is technological or design competition.

This method of awarding research and development contracts tends to further encourage design complexity and capacity. To minimize the risk of failure, source selection for the R&D contract is based upon design proposals and how well the technical, managerial, and physical resources of the firms are suited to the program tasks. There is more concern with the ability of the potential developer to deliver a system of adequate quality and reliability and to deliver that system on time than there is concern for differences in costs of the proposals of competing firms.

The technological complexity of most modern weapon systems means that transferring the production of an item from one firm to another, a necessary condition for viable price competition, is itself an extremely complicated process. One consequence of this fact is that technology transfers seem to take place most efficiently and rapidly when the two (or more) firms are in

direct contact. This, in turn, has important implications for the nature of the process of price competition.

C. VERTICAL INTEGRATION

The winner of the R&D award usually receives the initial production contract with sole-source negotiations for reimbursement and without consideration of other suppliers. It then has the inside track and a substantial competitive advantage for winning all contracts over the production life of the system which it developed. The expectation of follow-on production contracts is a major motivation for firms to compete for the R&D contract; revenues and expected profits are much greater for production than for research and development.

Under present procedures, if a firm wishes to be a candidate for selection as the prime production contractor for a major weapon system, it usually must be sufficiently vertically integrated to demonstrate a research and development capability as well as a production capability (the primary way to win the production contract is to first win the R&D contract). The same constraint frequently applies to subcontractors for major components of the system--the subcontractor might be required to design as well as produce the component.

There are valid reasons for assigning at least the initial production contracts to the developer of the system. Frequent and significant model changes are made during the initial stages of production, and production methods and tooling are not well defined. The developer's greater familiarity with the system at this stage instills an advantage for carrying out the necessary design changes. Separating production and design responsibility between two firms at this stage may be feasible, but will probably be more costly than coordinating both activities within the same firm.

Whatever its advantages, however, the requirement of a design capability increases the barriers to entry into the weapons production industry. This practice also reduces the scope of price-competitive reprocurement. The implicit tying of R&D and production contracts also precludes the opportunity to assign R&D and production to different firms according to their comparative advantage in the tasks.

D. BILATERAL MONOPOLY

Typically, the winner of the R&D contract eventually gains a monopoly advantage in the production of that system based upon its unique capabilities. Negotiations for contract prices take on the form of bilateral monopoly. The single seller-contractor negotiates with the single government agency-buyer. The result depends upon the relative bargaining skills of the parties and cannot be accurately forecasted.

Without the benefit of a market-determined price, the government is reduced to using informed judgment to evaluate the cost estimates submitted by the sole-source supplier when negotiating contract prices or determining reimbursement on cost-plus contracts. While the actual or potential competition from technically substitutable systems could exert some downward pressure on system costs, the monopoly producer will not be subjected to the pressure on costs usually expected in a more price-competitive market.

E. UNCERTAINTY, COMPLEXITY, AND COST PERFORMANCE

In terms of the risk of failure, the uncertainty regarding the technology for producing a new weapon system is not as significant as the uncertainty associated with the research and development of that system. However, it does have significant implications for the negotiation of prices or reimbursement rates, and for the scope for cost reduction as a result of

introducing a more competitive method of production source selection.

Because the system is new, and especially if its development has significantly expanded the technological frontier, the best way of producing it is simply unknown. The optimal production technique is a function of relative input prices, time to delivery data, and expected volume; it is discovered by analysis and planning and, more importantly, by actual production experience. Historically the unit costs of new products, both commercial and military, have been observed to fall as volume produced cumulates. The decrease in unit costs should be built into contract prices, but the rate of cost reduction is difficult to forecast. Just as the government is without a standard for determining the level of costs in a bilateral monopoly market, it is without a standard for evaluating the rate of cost reduction. Further, there is reason to believe that the rate of cost reduction is not technologically determined for a given system. Rather, it is a function of the effort which a firm expends on attempting to reduce those costs. In particular, that rate may be sensitive to the actual or potential level of competition for production of that system.

F. SUMMARY

The initial contracts and, often, all of the production contracts of a new weapon system are awarded to the developer of that system as a follow-on to the research and development contract. This practice precludes the opportunity for price-competitive selection of a different supplier and encourages the vertical integration of major weapon suppliers. The research and development of a new weapon system is subject to major uncertainties which differentiate it from most commercial markets where some degree of price competition is normally expected to exist. The uncertainties of the research and development of a new weapon system, and the follow-on nature of the production

contract, importantly influence the policies and practices which have developed for the procurement of weapon systems.

Several implications follow from the preceding discussion:

- Relative to other markets, those for weapon systems are characterized by:

  (a) a large amount of non-price competition;
  (b) a great deal of technological evolution of new products;
  (c) substantial uncertainty.

- The absence of price competition in weapon system markets is due, not to some intrinsic characteristics of those markets, but rather to policies employed by DoD. The fact that significant exchanges of highly sophisticated technology take place in the private sector suggests that price competition could be used in weapon systems acquisition process. Whether such a policy would prove cost-effective depends upon its benefits and costs. Previous examples of such competition provide the only evidence with which to judge this question.

- If price competition is to play a meaningful role in the weapon systems acquisition process, it will do so primarily at the reprocurement stage of that process. Prior to that stage, it is unlikely that the system is well enough defined to permit meaningful price competition.

- If price competition is to take place even at this stage, the transfer of highly complex technology must take place between two or more firms. The transfer of such technology is generally rather costly and proceeds most efficiently when there is direct cooperation between the firms involved. In addition, most of these costs are fixed in the sense of being largely independent of the number of units actually produced.

- Because of the uncertainty surrounding the development of a new product, the unit costs of production of weapon systems tend to fall as cumulative output expands. This suggests that, in general, a single producer can produce a given volume for less than the total costs that would be experienced by two producers.

For all of these reasons, the use of the price mechanism to allocate resources has been less prominent in the weapon system market than most other markets.

Chapter III

PRICE COMPETITION: THE SOURCES OF ADVANTAGES AND DISADVANTAGES

It is useful to separate into a number of categories the potential benefits and costs of using price competition in the reprocurement phase of the weapon systems acquisition process. Such a taxonomy, like any other, must be to some extent arbitrary; yet some classification scheme is essential if we are to distinguish among the various ways in which competition can influence the acquisition process and, in so doing, disentangle some of the factors at work.

We draw a basic distinction between benefits and costs--price effects and non-price effects. Price effects (benefits or costs) are those which are ultimately manifested in the unit price of the item whose production is being competed. That is, competition may lead to either higher or lower prices of the item procured than those prices which would have occurred under sole-source procurement. Non-price effects refer to all consequences of competitive procurement which are manifested in ways other than the unit price of the item being procured. As such, the non-price effects incorporate a variety of phenomena ranging from the costs of certifying new contractors to possible effects on the quality of the item. These non-price effects are further subdivided into categories called *quantitative* and *qualitative*. The former refers to effects which are readily translated into dollar sums (e.g., the cost of preparing a technical data package); the latter refers to those which are not (the impact of dual sources on logistics costs).

A. THE NATURE OF PRICE EFFECTS OF PRICE COMPETITION

The use of price competition can alter the unit price paid by the government for an item in a number of diverse ways. Perhaps the two most frequently cited arguments for the enlarged use of price competition are:

- The use of price competition will reduce the profits (perhaps excessive) of contractors;
- The rigors of competition will force contractors to utilize the most efficient techniques of production, thus reducing contract price.

It is important to realize, however, that the "case" for or against competition need not rest solely or even primarily on the presence or absence of evidence relevant to the two factors cited above. There are other ways in which price competition can influence the unit prices paid by the government for items they procure. For example, price competition can lead to the assignment of a production contract to the firm most efficient at that particular task and thus to a better matching of production requirements and contractor skills. These factors are briefly examined and analyzed below.

1. Contractor Profits

It is often alleged that defense contractors earn "excessive" profits. This would imply that private investment in weapon systems production systematically earns rates of return in excess of those required to attract capital into this industry. If this is so, then to the extent that these profits arise due to the absence of competitive pressures, price-competitive acquisition policies may lead to a reduction in DoD costs. The magniture of this potential benefit of competition will be determined by the magnitude of the profits earned in this industry and by the degree to which competition can provide DoD with alternative suppliers who are capable of limiting or reducing these profits.

The degree to which alternative suppliers can exert meaningful pressure on the original source and on each other depends upon the existence and relative efficiency of alternative firms. In effect, the price charged by the winning firm is limited by the threat posed by potential competitors. These relative efficiencies will in turn depend upon a variety of factors, including the advantages (if any) the original supplier has from having developed the system and the relationship between production costs and various dimensions of output.

2. Absence of Efficiency

It is frequently asserted that in the absence of competitive pressures, costs of production can rise due to the absence of incentives to minimize costs of production. Economists sometimes refer to this as X-inefficiency; it can develop whenever the discipline of a competitive market place is absent;[1] it may become more likely in the heavily regulated environment such as the one which characterizes defense contracting. In essence, while the lack of competition creates the possibility of very high rates of return, part or all of this potential return may be absorbed by larger than necessary costs, i.e., costs rise to absorb some or all of the excess profits.

The simple existence of such inefficiency does not assure us that an enhanced role for competition in the weapon systems acquisition process will eliminate it. For one thing, X-inefficiency may arise for reasons other than or in addition to the absence of price competition (e.g., government regulation). Secondly, it is likely that such inefficiency will not disappear from the operations of a firm simply because that firm is made to compete for a single or small number of contracts. Nonetheless, if such an inefficiency exists, competition may be a viable method for its removal.

[1]For the seminal work in this area see H. Leibenstein, "Allocative Efficiency vs. X-Efficiency," *American Economic Review* (June 1966).

3. The Efficient Assignment of Tasks to Contractors

As we have noted, most major defense contractors are vertically integrated in the sense of being involved in all phases of the development and production process. In the absence of post-design competition, the developer-producer of the system has a monopoly over all subsequent stages of the process. There are reasons to believe that some firms are more efficient at development, others at production. If this is so, competition at each sequential stage of the development and procurement process could lead to the assignment of each phase of that process to the firm best suited to undertake it. Such "efficient assignments" would raise allocative efficiency and reduce costs.

There are other reasons why the use of price competition might improve "assignment" and thereby reduce costs. At various times, individual firms encounter excess capacity. During these periods, such firms are likely to be willing to produce a given set of outputs for a lower price than they would require were they at full capacity. The amount of information that would be required for the government to directly detect such "special situations" would be enormous and, very likely, prohibitively costly. An alternative means of detecting and taking advantage of such situations would be through the solicitation of price-competitive bids.

4. Empirical Estimation of Price Effects of Price Competition

All of the factors mentioned above could cause the unit prices paid by DoD under competitive procurement to be above or below those that would be experienced under sole source procurement. There are several ways in which the existence and magnitude of such costs and, hence, of the related potential benefits of competition might be estimated.

a. General Estimates

First, if such excessive costs or profits exist, either the costs of items acquired by DoD should be systematically higher than the costs for equivalent non-DoD equipment, or above normal rates of return should be earned by defense contractors. The former hypothesis can be tested by defense/non-defense commodity cost comparisons, although selection of "comparable" defense and non-defense items is inherently difficult. This approach was taken in an earlier IDA study.[1] The tentative conclusion reached was that defense items did not cost more than their non-military equivalents.

In order to test the latter hypothesis, we can compare rates of return to capital in defense-related industries with other industries of comparable risks. Again, a number of difficulties are likely to be encountered due to the difficulties in defining and measuring both the confines of the defense-related industry and selecting suitable measures of risk.

A number of such studies of defense industry profits have been undertaken in the past. These have ranged from highly polemical efforts to rather sophisticated analyses. Many of them were surveyed in the 1974 IDA study. Among the problems encountered by such studies is the fact that many weapons manufacturers are engaged in a variety of other areas; as a result, it is difficult to isolate the rates of return earned on defense contracts. The general conclusion of the professional literature is that defense contractors have *not* earned excessive rates of return.

Several additional problems are associated with the general measures discussed above:

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[1]M. Zusman, *et. al.*, *A Quantitative Examination of Cost-Quantity Relationships, Competition During Reprocurement and Military Vs. Commercial Prices for Three Types of Vehicles*, IDA S-429, March 1974.

- The measures are not exhaustive. As already noted, competition may, through a better matching of contractors and tasks, reduce unit prices even though neither technical inefficiency nor excess profits are experienced by original suppliers.
- Precisely because such measures are so general, they do not provide insight into the particular economic or technical characteristics of specific competitive processes and/or weapon systems which lead to cost savings. Thus, they are not useful to the establishment of criteria which can guide managers in specific situations.

b. Examination of Specific Competitions

The second basic source of evidence regarding these factors are the results of earlier competitions which, while rare, should provide useful insights. In a number of instances the services have "broken out" an item for competition. The results of these competitions provide the most direct evidence available for judging the results of price competition and are examined in greater detail in Chapter VI.

It is important to determine how representative such evidence is in order to judge how applicable or inapplicable it is to other areas where competitive bidding might be utilized. In particular, were the systems selected for competition because of evidence that the sole-source producer was not performing adequately? Are there technical characteristics of the systems which separate them from more general types of DoD acquisitions? To what extent did the competitive process typically change other dimensions of output (e.g., planned buy) and in what ways did this influence the apparent effects of competition? The earlier evidence and that collected subsequently will be evaluated with this in mind.

B. THE NON-PRICE EFFECTS OF PRICE COMPETITION

The decision to utilize price competition in determining who will produce a weapon system inevitably involves costs and

benefits external to the contract prices of the system itself. These effects are all broadly associated with the actual or potential transfer of technology from the original supplier to other firms and take diverse forms. Some involve payments by the government to the original supplier or to alternative suppliers. Others, such as time used to evaluate proposals and to monitor contractors, require the use of the government's own resources. Still others have impacts which, while difficult to express in dollar terms, are nonetheless real. These we call *qualitative effects*.

1. Explicit Costs

The decision to utilize competition requires explicit expenditures for a number of things, most of which are related to the process of technology transfer. These costs include:

(1) The costs of acquiring a technical data package and other relevant proprietary data from the original producer, as well as any costs due to defects in those data;

(2) Non-recurring costs paid to the original source to impart information to the second source, and to underwrite learning or qualifying quantities for that source;

(3) The costs incurred by all firms in preparing proposals, costs which may reappear in other contracts.

2. Implicit Effects

The use of price competition also requires the use of government resources in the allocative process. Examples of these sorts of costs are:

(1) The costs of preparing the RFP, evaluating proposals, and negotiating contracts;

(2) The costs of monitoring contractor behavior;

(3) The costs associated with engineering change orders and other possible impacts of competitive contracting.

The use of price competition to allocate production during reprocurement can also reduce costs. For example, the expenditures made to audit and monitor a sole-source producer (e.g., "should cost" studies) can be reduced.

3. Qualitative Effects

A number of potential impacts of price competition are manifested in ways which are difficult to express in monetary dimensions. These include:

(1) Effects in terms of logistics;

(2) Possible delays in the delivery of items;

(3) Effects on the quality of the item;

(4) Impacts on the mobilization capacity of the industry;

(5) Impacts on the structure (e.g., number and viability of firms) in the industry.

4. Effects on Other Phases of the Weapon Systems Acquisition Process

It is frequently alleged that the potential profits associated with production of weapon systems, combined with the emphasis on technological or design competition at the research and development stage, result in "buy-ins," i.e., firms deliberately subsidizing their research and development efforts in hopes of recouping those costs if they win the subsequent production contract. If the use of price competition to assign production removes any extra-normal returns earned under sole-source procurement policies, firms will no longer be willing to subsidize their research and development activities in order to obtain those returns. As a result, the costs of earlier phases of the weapon systems acquisition process will rise, and some part of the apparent savings from competition will have proved illusory.

Whether such a consequence of the use of price competition will follow depends on several factors:

- Whether buy-ins are a quantitatively significant factor in the weapon system acquisition process;
- Whether the use of price competition would, on some acquisitions, reduce the prominence of buy-ins for those and/or other acquisitions.

Obviously, both the existence of buy-ins and the possibility of price competition affecting them is an extremely complex issue. It will not be considered here other than to note several factors:

- The "case" for competition does not rest solely on the existence of excess returns in weapon systems production. That is, even if buy-ins do exist and price competition eliminates them, thus raising the costs to the government of weapon systems development, the "case" for enhanced price competition would not disappear.
- Our analysis, in ignoring the effects of price competition in reprocurement on other stages of the weapon systems acquisition process, tacitly assumes that these effects are quantitatively unimportant. This assumption should be understood in evaluating our results.

Chapter IV

THE CENTRAL ISSUES: COST-QUANTITY RELATIONSHIPS AND TECHNOLOGY TRANSFER

The purpose of this study is to identify the potential benefits and costs arising from the use of price competition during procurement and to develop the criteria for determining when the use of such competition is appropriate. While a variety of diverse factors combine to determine the net benefits of price competition during weapon systems production, many of these factors can be placed into one of two general categories of phenomena which, accordingly, must play a prominent role in any discussion of this topic. These are:

- Cost-Quantity relationships and, in particular, the so-called progress or learning curve phenomenon;
- Technology transfer and, more specifically, the costs of transferring knowledge and the associated proprietary rights between firms.

A. THE NATURE OF THE PROBLEM

Price competition has both potential benefits and potential costs. Its primary benefit arises from the fact that it can force down the price of the item being competed. To know how far that price has been bid down, we must know the price that the original sole-source supplier would have charged had competition not taken place. Such a price is, of course, not directly observable; therefore it has to be estimated. Central to such an estimation is the relationship between the costs experienced by the sole-source supplier and the number of units

he has produced. This relationship is commonly referred to as the *learning* or *progress curve* and is of critical importance to estimates of the benefits of price competition.

Obtaining benefits from price competition depends upon the actual or potential transfer of production between firms. Such transfers utilize resources and, therefore, generate costs. Such costs are the primary ones associated with the use of price competition to allocate production and thus importantly influence the existence and magnitude of the net benefits of competition.

Accordingly, these two issues--learning curves and other cost-quantity relationships on the one hand, technology transfer on the other hand--play a central role in the discussion of this topic.

B. COST-QUANTITY RELATIONSHIPS

1. Learning Curves

In order to evaluate the winning bid in a price competition, we have to estimate the price that would have prevailed had that competition not taken place. Unfortunately, this is not a simple matter. Most weapon systems which are entering the reprocurement stage are relatively new and the methods by which they are produced are evolving. A wide range of experience, from both the defense and non-defense sectors, indicates that these changes lead to reductions in the real unit costs of production over time.[1] Thus, even in the absence of competition, we would expect a reduction in unit cost as the sole-source's cumulative production expanded.

The relationship between unit cost and cumulative output is variously referred to as a progress, experience, learning or

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[1]The classic references is H. Asher, *Cost Quantity Relationships in the Airframe Industry*, RAND Corporation, R-291, July 1956.

cost improvement curve; we use these terms interchangeably.[1] Typically, such curves are estimated as log linear functions which plot as straight lines on logarithmic scaled graphs and are of the general form

$$C = AN^{-B}$$

where C is the unit (marginal) cost, A is the cost of the first unit, N is the number of units produced, and B is the progress curve exponent.

The exponent B defines the slope of the learning curve.[2] The larger its value, the steeper the slope of the learning curve and the more rapidly the unit cost falls with the expansion of cumulative output. Because of their expression in logs, learning curve slopes refer to percentage changes in costs and outputs. Thus, a learning curve with an 80 percent slope is one for which unit costs will fall by 20 percent when output doubles.

a. Alternative Causes of Learning Curve Phenomena

The explanations for the cost reductions expressed by learning curves reflect the variety of forces that underly the measured relationships. The industrial and production management literature suggest that unit costs fall with planned volume because of factors such as job familiarization, general improvement of coordination, shop organization and engineering liason, more efficient sub-assembly production and more efficient tools.

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[1] Costs analysts prefer to think of learning curves as a relationship between labor hours per unit and cumulative output. The nature of our interests as well as the data we examine require that we instead consider the relationship between all components of unit cost and output. We use this wider definition throughout this paper.

[2] The relationship between the exponent B and the slope of the learning curve is: log (slope in percent/100)/log 2 = $-B$ or slope in percent/100 = 2^{-B}.

On the other hand, several economists have argued that the negative slope of the learning curve can be rationalized in other ways [Alchian, 1959; Oi]. Specifically, they would argue that what is called a learning curve is also caused by such factors as adjustments of production techniques and intertemporal substitution in response to larger planned volumes.

There are, then, two basic explanations which have been offered for the observed learning curve phenomenon:

- The traditional one, namely, that with experience better techniques are developed and these serve to reduce unit costs. We call this the "technological change" explanation.
- The Oi-Alchian explanation, namely, that larger planned volumes reduce unit costs by allowing better intertemporal substitutions among inputs. We call this the "planning" explanation.

Which of these explanations, or rather the degree to which each accounts for observed learning curve relationships, can have important implications for the results of price competition. If the observed learning curves result from the adjustment of production techniques to planned volume and to the benefits of intertemporal substitution and joint production, there is little scope for maintaining the learning curve effects of volume while splitting the production between two contractors. Splitting or threatening to split production between two producers will, for example, encourage the use of less durable and less specialized equipment with a resulting loss in economies of volume. The opportunity for intertemporal substitution of inputs is also reduced by splitting production runs.

To the extent that the inverse relationship between average cost and cumulative volume is due to changes in technology derived from experience, there is more hope for maintaining continuity of the learning curve if production is allocated either simultaneously or sequentially between two producers. The acquired technology is embodied in the equipment, processes, and

labor used for production, and can be transferred between producers. The issue becomes: At what cost can the technology be transferred? This issue is discussed in Section C.

b. Other Characteristics of Learning Curves

Several other characteristics of learning curves deserve emphasis at this point. The first we have already touched upon, namely the *pervasiveness* of the phenomenon. Although variations between items are large, many civilian manufacturing processes cluster around 80 percent while weapon system progress curves are somewhat less steep.

Second, at least over production runs of substantial length, the learning curve often tends to *flatten out* as cumulative volume expands. As a result, the log-linear function, while useful for purposes of statistical estimation, is only an approximation of the underlying relationship and one which tends to overstate the degree of cost reduction. There are several explanations for this. One is simply that the returns to investment learning diminish with increases in output. The other is that, even if all of the components of a commodity individually exhibit log-linear curves which are not identical, the composite (commodity) learning curve will not be log-linear but instead will "flatten out." This will occur because, as output expands, those components which have "flatter" learning curves will represent even larger proportions of total costs.

Finally, learning curves tend to be highly *unstable.* Alchian (1963) attempted to predict the learning curves of a variety of aircraft models. Whether the predictions were made based upon general experience or early production data from a specific model, errors of prediction averaged nearly twenty-five percent. These findings cast serious doubt on the use of learning curves for cost predicting purposes, particularly when the cost estimates have to be based on long range extrapolations.

2. Other Dimensions of Output

A statistically derived learning curve is often used to illustrate the relationship between unit costs and accumulated (past) output.[1] However, a variety of research suggests that the cost of production depends upon other dimensions of output as well. Other variables which have been emphasized in these discussions are:

- The *rate* at which output is produced;
- The *planned future* volume of output;
- The *time horizon* over which the output is to be delivered;
- Production lot size.

These other factors are important to our analyses of price competition because the use of the competitive process may entail or imply changes in one or more of these other dimensions of output. For example, the decision to have a "buy-out" may well suggest to potential bidders that future planned volume will be large. Alternatively, a split-buy may reduce the rate of output of a formerly sole-source producer. For these reasons, price competition should be expected to influence cost-quantity relationships in a number of ways. It is important, therefore, that in interpreting the evidence provided by earlier price competitions, we be aware of the other influences on unit cost.

The point is illustrated in Figure 1 below by three unit cost progress curves. The first, C_oC_o, is the learning curve projected from original sole-source data. It assumes (at least implicitly) a particular lot size, L_o. Now, suppose that simultaneously with utilizing price competition, DoD expands lot size to

[1]See A. Alchian, "Cost and Outputs," in M. Abramovitz, *et. al., The Allocation of Economic Resources,* Stanford 1959; "Reliability of Progress Curves in Airframe Production," *Econometrica* (October 1963); H. Hirschleifer, "The Firms Cost Function: A Successful Reconstruction?" *Journal of Business* (July 1962); Walter Y. Oi, "The Neoclassical Foundations of Progress Functions," *Economic Journal* (September 1967).

$L_1 > L_0$. This latter change alone should have an impact on unit cost independent of that exerted by competition. The effect of this latter change would be to shift the entire progress curve in a fashion directed by the precise form of the relationship between lot size and unit cost. In our example, we assume that larger lot size leads to a reduction of unit cost so that the second projected progress curve, C_1C_1, lies below the initial one. In other words, C_1C_1 is the projected progress curve adjusted for the change in the dimensions of output associated with competitive procurement. Obviously, we should anticipate a reduction in the price of the commodity even in the absence of competition. Finally, C_2C_2 is the post-competitive progress curve associated with the new, larger lot size L_1.

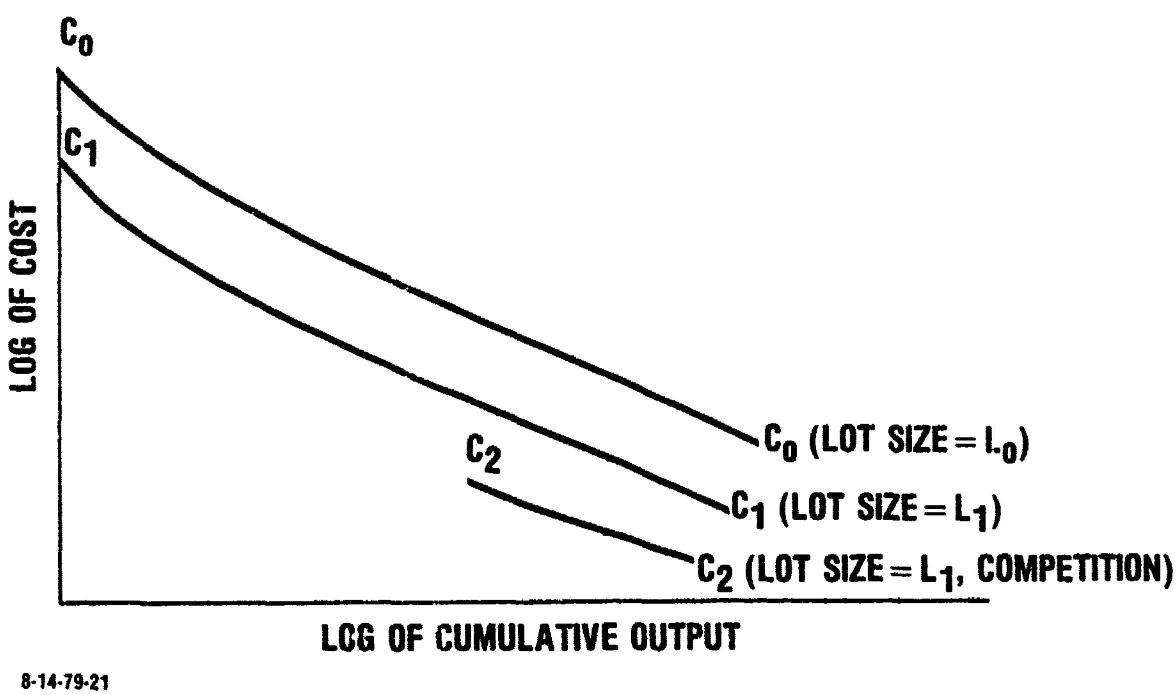

Figure 1. SHIFTS IN PROGRESS CURVES

3. Methods of Estimating the Price Effects of Competition for Specific Systems

The sorts of price effects discussed above can be at least partially decomposed; the nature of this decomposition and the information it requires are shown in Figure 2.

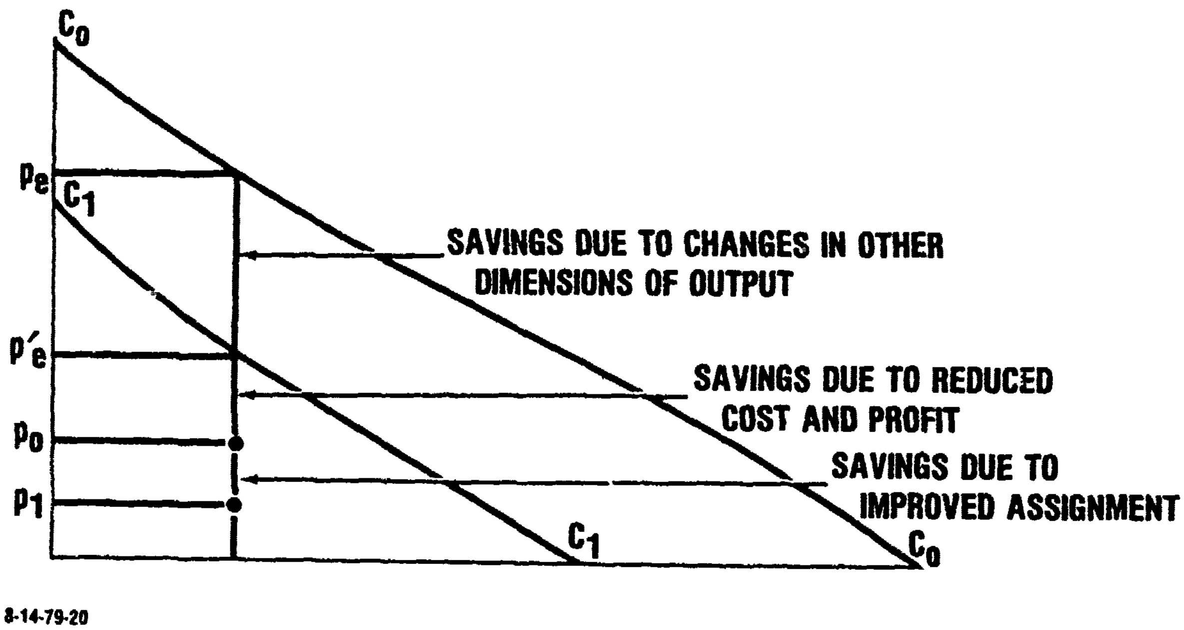

Figure 2. DECOMPOSITION OF UNIT PRICE REDUCTION

Suppose that the projected sole-source learning curve is C_oC_o and that the adjusted (for altered dimensions of output) sole-source learning curve is C_1C_1. Suppose further that the competition is won by a second source with a price of p_1 and that the original sole-source had a bid of p_o.[1] We assume that all progress curves are accurate and that all bids made under competitive circumstances reflect actual costs.

[1]Of course there is no reason to necessarily suppose that the second source will have a bid lower than the original source.

p_e is the price that we would expect based upon the experience of the original producer. However, p'_e would be projected given the change in other output dimensions which accompany the competition. Thus, the change $p_e - p'_e$ is due solely to these factors and should not be attributed to competition. Of the remaining change $(p'_e - p_1)$, the difference between the original producer's adjusted projected price, p'_e and the price he bid, p_o can be attributed to either greater efficiencies he has achieved or, alternatively, to a reduction in his profits. The remaining difference, reflecting the difference between the original source's bid and that of the winner, $p_o - p_1$, is attributable to the better assignment achieved through the competitive process.

C. TECHNOLOGY TRANSFER

A transfer of technological knowledge is required for candidate firms to develop cost proposals and for the winning contractor to produce an adequate system. Such a transfer may be accomplished with a technical data package (TDP) which provides the specifications of the article to be produced. More complex systems, however, are often inadequately specified and the TDP is insufficient to support a simple formally advertized invitation-for-bid (IFB) competition. Some form of direct technical assistance from the developer to the second source is required; the second source may also need production experience before it is prepared to bid competitively for a firm fixed-price contract.

In general, the more complex the item the more time consuming and expensive is the transfer of technology, but (as with most technical and economic transactions) trade-offs are possible. For example, an item which could feasibly be transferred with only the use of a TDP might be transferred with less risk, but greater expense, by the provision of direct technical assistance and a series of non-competitive learning buys for the

second source. The time required to affect a transfer of technology might also be reduced by incurring greater costs and more risk.

Establishment of price competition will often require substantial external time and cost to select and qualify a second source and to transfer the technology from the developer. Those costs include in-house government administration costs, the costs of acquiring rights to use proprietary data, preparation of the technical data package, learning buys awarded to the second source for production of articles destroyed in testing, extra testing required to qualify the second source, and the extra cost of pre-competition production of articles by the second source required to gain experience.

Introduction of competition may therefore be inhibited by constraints on funds and personnel required to affect the transfer of technology. Another impediment to successful technology transfer is the lack of incentive for the original developer to cooperate. Firms are reluctant to supply information which diminishes their competitive edge in defense and commercial markets, and because of poorly defined property rights, there are potential disputes over ownership and protection of proprietary data.

The remainder of this chapter summarizes literature on government policy with respect to proprietary rights and the acquisition and transfer of technical data. This discussion is subordinate to the main body of the report and is not required for continuity. Many of the problems mentioned in the literature were confirmed in interviews with Service personnel and are summarized in Appendix G. Chapter V presents the techniques available for introducing competition and accomplishing the transfer of technology.

1. The Value of Information

Successful technology transfer depends on who has the rights in data, the incentives which all parties have to cooperate, and the cost of implementation. During the research and development and the manufacturing phase, information, as well as a weapon system, or component, is produced. This information is useful and often necessary for the manufacture of identical components and spare parts by any firm other than the original contractor. Because the government finances the research and development, in the past it presumed that it had proprietary rights in all necessary data. The private firms have contested that view; they argue that they use technological expertise in producing a particular component which they previously developed at their own "private" expense. The firms have claimed proprietary rights in such trade secrets and have refused to voluntarily surrender them. The problem results from a breakdown in property rights laws which make protection of rights and marketability of those rights difficult.

Proprietary information is a form of product differentiation. The firm which developes a particular system has a virtual monopoly on that particular system and can expect to extract at least some of the potential rents from government payments for future production. A manufacturing process used in a particular weapon system might be applicable to other defense or commercial systems as well. Thus, the value of such firm-specific (as opposed to system-specific) data is potentially greater to the private firm than it is to the government because of the commercial applications [McKie, 1966, pp. 21-3].

One potential upper limit to the value of a particular package of proprietary information is the value of the competitive edge it imparts to the firm in all revelant markets. The value to the goverment is also limited by the cost of the combined development, production, testing, and logistic cost of

alternative designs from other prospective suppliers, and the cost of reverse engineering--the determination of how a component is produced from only engineering analysis of the component itself. The maximum that the government would have to pay for rights to proprietary data is the lesser of the three potential limits.

2. Government Policy

Government policy as embodied in Armed Service Procurement Regulations, Section 9 (ASPR-9), is one of limited rights [McKie, 1966, p. 23]. Under this policy, the government has unlimited rights to data actually produced in the course of a research and development contract funded by the government. Data developed by firms at private expense may be acquired with only limited rights. In particular, limited data may not be disseminated by the government to other firms to support competitive bids or production by those firms. In an effort to avoid later controversy over gray areas, the contracting parties may use the predetermination clause to settle questions regarding rights to data. Given the indefinite "private expense" criterion and the government's negotiating strength at the beginning of the R&D phase, almost any result is possible. In particular, a licensing agreement including the determination of fees and royalty payments can be arranged before the R&D program begins.

3. The Cost of Technology Transfer

Successful transfer of technology incurs three kinds of direct costs: costs of acquiring rights in data, cost of data management, and the cost of technical assistance. Rights to data generated by the contracted research and development are government property, but rights to proprietary data developed by the contractors at private expense must be purchased. As discussed above, the maximum which the government should pay for such data is the lesser of the value to the firm in all

applications, the cost of alternative development, or the cost of reverse engineering. However, the government should be able to reduce acquisition costs by careful predetermination of which data are to be regarded as proprietary, and of the price of acquisition. The need for proprietary data might also be reduced if, during the program definition phase, the government insists on the use of standard parts whenever possible. Provision of form, fit, and function data can often enable the production of an acceptable substitute without the use of proprietary data.

In the past, the government has attempted to collect all the data regarding a weapon system whether or not it is expected to be used. That policy, combined with the reluctance of the contractors to reveal proprietary data and the frequent design changes during the early stages of production, resulted in the acquisition of vast amounts of incomplete and obsolete data [Johnson and McKie, p. 7]. In an effort to reduce data handling costs the government now generally acquires only data which it expects to use and delays collecting it as long as possible so as to avoid obsolescence.

For practical purposes, *rights* in data must be distinguished from *access* to data. In some cases, even if the government has rights in data, it may be worthwhile to pay the contractor for access, that is, for assistance with technology transfer. To quote McKie [1966, p. 39]:

> There is scattered evidence that for products or for processes of any complexity--those most likely to involve "proprietary" techniques under the old definition--the manufacturing drawings themselves are not enough, even though prepared in good faith by the manufacturer. There commonly seem to be some shop practices, plant layout, tooling, pragmatic experience, and know-how which cannot be transferred by the "data" medium. When alternative sources are developed in such circumstances it has generally been necessary for this supplementary know-how to be transferred by a process of in-plant

schooling or direct training, master tooling, observation--a direct contact between originator and transferee.

Firms must be compensated for the expenditure of resources required for direct technological assistance. Payments contingent on the successful transfer of technology are also more likely to encourage compliance and improve the data flow. This means that the successful use of price competition is likely to involve direct contact between the original sole-source supplier and his potential competitors. Such competition is commonly referred to as "leader-follower."

Granted that the transfer of technology is feasible, the primary issue concerns the magnitude of the costs generated by the process. Ultimately, of course, this is an empirical question that can be resolved by observing whether reasonably conducted competitions have proved to be cost-effective investments. Nonetheless, several general points are worth noting.

First, technology transfer among complex products is a common and indeed pervasive aspect of modern industrial economies. The sudden rise (and fall) of corporations which produce expensive and complex products repeatedly demonstrates the economic viability of technology transfer. Many corporations have succeeded as enterprises primarily on the basis of their ability to produce technologically advanced products originally developed by other firms. There is substantial evidence that this is also true of military systems [Hall and Johnson, 1968].

Second, the costs incurred in transferring technology between producers appear to be essentially independent of the number of units that are produced, although the type of technology transferred may depend on the number of units planned to be produced. This has clear implications for the nature of cost-effective investments in price competition for weapon system reprocurement, namely, that systems for which large

procurements are anticipated will, other things equal, be better investments than those for which small purchases are likely.

The cost of data transfer will differ from system to system, but it should decrease over time. Just as the costs of production drop with experience, so will the costs of technology transfer. Firms will anticipate problems; controversial points will be reduced to the routine; a division of one firm will become more adept at communicating with other firms; to the extent that firms essentially specialize in R&D, production cooperation will appear less threatening.

4. The Time of Transfer

The decision of when to introduce competitive procurement depends upon the relative costs of technology transfer. The earliest possible time is, of course, before production begins. One advantage of competitive bidding at this stage is that a greater share of the production run is subject to the downward pressure on prices. Less information must be transferred at this stage; in particular, proprietary manufacturing process information will be a less significant share of the total data package. In fact, there is some doubt regarding the usefulness of much of the R&D data for developing manufacturing processes. Of course, there is no concern with the potential loss of the benefits of experience in production because none would have taken place.

On the other hand, there are significant problems which can result if technology transfer takes place before production begins. First, the design is less certain, and changes are frequently made during the initial stages of production. It is probably better to leave the design responsibilities with the original developer rather than with the new producer. The problems are not insurmountable, but at a minimum, the costs of coordination and communication would probably be higher than

if the developer and manufacturer were one and the same. Also, although less information is available for transfer at this stage, it makes the developer appear less cooperative. Most trouble with licensing arrangements in the past has occurred when the licensor-developer has had no actual production experience with the system before the technology transfer occurred [Carter, p. 36].

As competitive procurement is postponed into the production cycle, the benefits and costs tend to reverse. There is more information to transfer, but it is more helpful to the new producer and less subject to obsolescense by a design change. The original producer will have acquired considerable experience which may not be completely passed on. The benefits of competitive pressure on prices are forgone for all units produced under sole-source arrangements. It would also seem that the more experience one has with production, the greater its advantage during the competitive bidding. That could discourage other firms from incurring the costs required to submit a bid.

In summary, while there are both advantages and disadvantages associated with it and while the size of these benefits and costs may be expected to vary across systems, there are strong reasons for supposing that technology can be most efficiently trarsferred *after* initial production has taken place. Put differently, initial production is best viewed as a continuation of the RDT&E phase of the development process. Thus, price competition will, in general, be most advartageous if it is used at the reprocurement stage.

5. Conclusions

Several conclusions emerge from the preceding discussion. Those which are of greatest importance to this study are:

- *Repeated evidence suggests that technology transfer is feasible at reasonable cost.* As the government and contractors gain experience, the transfer costs

should decrease. Many of these costs are fixed and, hence, the volume of planned procurement must be substantial to justify them.

- *A reliable and complete data package is helpful, although in many cases it may be insufficient by itself.* Successful transfer of some systems requires information on manufacturing processes and practices which is better transferred by direct contact between the original developer and the new supplier than by the data medium.

- *The major hurdle to successful technology transfer in the weapons industry is the lack of incentive to cooperate.* There are potential disputes over ownership and protection of proprietary data. Firms are understandably reluctant to transfer information which may reduce their competitive edge. However, the problems could be substantially overcome by careful predetermination of which data are to be regarded as proprietary and the price for acquisition and transfer of such data. Licensing agreements could be negotiated during the source selection process for the original research and development award. Such agreements should provide reimbursement to the originator for successful technology transfer to and production by the second source in order to compensate for the costs of transfer and to improve incentives for cooperation and efficiency. Royalty payments would be made for access to the technology, not for the rights which the government might already own.

- *The problem of transferring proprietary data also can be alleviated by the use of standard parts wherever possible.* Provision of form, fit, and function data may eliminate the need for transfer of proprietary data altogether for some system components.

- *It is likely that the technology transfer required for the use of price competition can occur most efficiently after initial production by the developing firm has taken place.* This suggests that the primary role for the use of price competition will be during the reprocurement phase of the weapon systems acquisition process.

Chapter V

TECHNIQUES FOR IMPLEMENTING COMPETITION

A. INTRODUCTION

This chapter includes a brief description of the elements and the relative advantages and disadvantages of each of the techniques available for introducing competition. Guidance for the use of the various techniques is given by the Defense Acquisition Regulations (DARs), formerly the Armed Services Procurement Regulations (ASPRs).[1] Alternative techniques are required to match the circumstances surrounding the competition and technology transfer of different systems.

There is a basic asymmetry in the competition for reprocurement contracts of a major weapon system or component. One or more firms with no production experience must be solicited to compete with a firm which is not only experienced in the production of the item, but is likely to be the developer as well. New firms must become sufficiently familiar with the item to establish cost estimates in which they have reasonable confidence before they can compete effectively.

For simple items, the technology may be adequately transferred by means of the technical data package (TDP); new firms can submit competitive bids before they actually produce the item. More complex systems may require more comprehensive technology transfer and some actual production experience before the new source can realistically compete with the original developer-producer. Generally, the less well-specified the design and the

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[1]References throughout this Chapter are to relevant paragraphs of the ASPRs as reported in the *Government Contracts Reporter* published by the Commerce Clearing House, Inc.

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more complex the item to be competed, the more costly and time consuming is the development of the second source.

B. ADVERTISED PROCUREMENT (P3000)

1. One-Step Formal Advertising

Government policy states that "all contracts for supplies and services, military and civilian, be made by formal advertising unless negotiation is specifically authorized by statute" (P3015). The technique, referred to as IFB or formal advertising, requires that invitations for bids (IFBs) be formally advertised.

One-step formal advertising is appropriate when the design is well specified and the technical data package (TDP) is sufficient for transfer of technology. The bids must be submitted by responsible bidders and be responsive to the invitation (P3530). However, screening of the bidders for technical capability and understanding of the design is limited. A fixed-price contract with or without escalation provisions is awarded to the winner of the competition (P3015). The award must be made to the responsible bidder with the lowest bid unless non-price factors for evaluation are specified in the IFB.

The advantages of one-step formal advertising are that it is faster, easier, and less costly to administer than other techniques. On the other hand, it is insufficient for many systems: production data are insufficiently specified in the TDP; firms cannot make reasonable cost estimates to support their bids; or the government's scope for evaluation of the contractors' understanding of the design and plan for production is limited. New contractors occasionally encounter unforeseen production problems after receiving the award. This results when the TDP is incomplete and the new source does not have the engineering capability to fill in the gaps.

2. Two-Step Formal Advertising (P3700)

Two-step advertising can be used when all of the following conditions exist:

(1) There are no sufficiently definite or complete specifications or purchase descriptions available to permit free competition without engineering evaluation and discussion of the technical aspects of the procurement;

(2) Criteria exist for evaluating technical proposals, such as design, manufacturing, testing, and performance requirements, and special requirements for operational suitability and ease of maintenance;

(3) It is expected that more than one technically qualified source will be available, both initially and after technical evaluation;

(4) A firm fixed-price contract or fixed-price contract with escalation will be used. (3700)

The extra step consists of the request, submission, and evaluation of a technical proposal to determine the acceptability of the production plan. The second step for price bids and award proceeds as in one-step, except that IFBs are issued only to contractors whose technical proposals have been accepted.

Use of two-step formal advertising tends to discourage less qualified firms because of the cost of submitting a proposal. The first step requires the firms to become more familiar with the design before submitting bids. It also allows the government to more effectively screen candidates with respect to technical capability and understanding.

The use of a fixed-price contract may be too rigid and risky for a firm to bid on production of a system with which it has no production experience. The TDP may be inadequate to transfer technology without significant engineering effort to overcome the deficiencies and reconcile the plant layout and production processes with the design specifications. The cost of such effort may be so unpredictable that new firms might be inhibited from bidding for a fixed-price contract.

C. NEGOTIATED COMPETITION

For systems whose characteristics cannot be adequately described in the specification, the procurement may be negotiated rather than advertised. As stated above, this is often the case with complex systems: the TDP is inadequate to communicate the production requirements. Negotiated procurement is defined as procurement of supplies and services by the government without the use of formal advertising (P5020). The use of negotiation is limited by statute and regulation because of the possibility that it might restrict competition. It should be added that it is a general requirement that even negotiated procurements be competitive to the extent possible.

Negotiated procurement may be used in 17 specific situations if advertising is not feasible and practicable. The exceptions are:

1.	National Emergency	5110
2.	Public Exigency	5115
3.	Small Purchases	5120
4.	Personal Services	5125
5.	Services of Educational Institutions	5130
6.	Purchases Outside the United States	5150
7.	Medical Supplies	5155
8.	Property Procured for Resale	5160
9.	Subsistence Supplies	5165
10.	Competition Impracticable	5180
11.	Research and Development	5185
12.	Classified Purchases	5190
13.	Standardization Required	5195
14.	Substantial Initial Investment	5200
15.	Negotiation after Advertising	5205
16.	Industrial Mobilization	5210
17.	Other Legal Authorization	5225

Exception 16, Industrial Mobilization, is the most frequently used exception to justify negotiated *competition.* It is the only exception which explicitly allows concurrent procurement from more than one firm and, possibly, at different prices. A stylized sequence of the use of negotiated competition includes the following steps.

(1) The contractors develop technical proposals, during which time they can examine the TDP and often a copy of the article to be produced. Based on cost, technical, and management proposals, a second source is selected and awarded a contract for production of a few items for first article testing. This is not necessarily a fixed-price contract.

(2) When the items are qualified, an option to the first contract is exercised or a new contract is awarded for a small learning buy. That may be followed by a few more non-competitive contracts to provide sufficient experience for the second source.

(3) When the second source is deemed capable, a series of split-award competitions is carried out for the annual procurement requirements. The contractors are requested to submit a series of step bids for, say, thirty to seventy percent of the total annual requirements stated in increments of five percent. The government then selects the most advantageous combination of bids and splits the award accordingly.

(4) After the second source has gained sufficient experience to be competitive with the original contractor, the series of split awards may be followed by an all-or-nothing competitive buy-out. The winner is awarded a multi-year fixed-price contract with an escalation clause. Options may also be included to cover any unforeseen future increases in system requirements. A competitive buy-out may not take place if two firms are desired to meet mobilization base requirements or because multi-year contracts are believed to be unworkable (see Chapter X, Section B).

Risk, both for the second source and for the government, is reduced considerably by the use of negotiated competition and the sequence of contracts as outlined above. The second source is not required to compete for a firm fixed-price production contract until it has production experience with the article; it is less likely to encounter financial or technical difficulties under this arrangement. If it does, the first contractor is still available to cover any production deficiencies. Also, by postponing actual price competition for production until the second source has sufficient experience, a more realistic price is obtained and the government has greater assurance of receiving timely delivery. The disadvantage,

of course, is the extra time, effort and cost required to establish a second source in this manner.

D. PROVISION FOR TECHNICAL ASSISTANCE

For some systems, the technical data package is inadequate for the transfer of technology, or it is deemed desirable to augment the TDP with direct technical assistance for the new source from the original developer-producer. The problem of obtaining technical assistance as well as the TDP is one of incentive for the original source to cooperate. Compensation for the cost of technical assistance provided by the original source may not be sufficient motivation.

At least three methods to provide technical assistance have been used, are presently used, or have been proposed. The key to each of the methods is early negotiation of the conditions of the contract while the government has sufficient competitive leverage to obtain cooperation. As well as facilitating the transfer of technology, these methods may also shorten the lead time required to develop a second source. The second source may be selected and production initiated before the TDP is actually validated by production, if direct technical assistance is substituted.

1. Leader-Company Procurement

The Army Missile Readiness Command (MIRCOM) has used, and the Air Force has plans to use, a method known as leader-company (or leader-follower) procurement. The objectives, limitations, and procedures are spelled out in ASPR4-701 to 4-703, (P33,067-9), reproduced as Figure 3.

As used, the procedures differ as to whether the government or the leader company selects the follower company, and whether the government awards a contract directly to the second source. The intent of the technique is to provide assistance from the leader company to the follower company. As interpreted by

Part 7—Leader Company Procurement

[¶33,067]

4-701 General. Leader company procurement is an extraordinary procurement technique under which the developer or sole producer of an item or system (the leader company) furnishes manufacturing assistance and know-how or otherwise enables a follower company to become a source of supply for the item or system. This technique is used to accomplish one or more of the following objectives.

(i) shortening the time for delivery,

(ii) establishing additional sources of supply for reasons such as geographical dispersion or broadening the production base,

(iii) making maximum use of scarce tooling or special equipment,

(iv) achieving economy in production,

(v) assuring uniformity and reliability in equipment performance, compatibility or standardization of components, and interchangeability of parts,

(vi) eliminating problems in use of proprietary data not amenable to other more satisfactory solutions, or

(vii) effecting transition from development to production and to subsequent competitive procurement of end items or of major components.

[¶33,068]

4-702 Limitations on Use. Leader company procurement is to be used only when all of the following circumstances are present

(i) the leader company possesses the necessary production know-how and is able to furnish the requisite assistance to the follower,

(ii) no source of supply (other than a leader company) would be able to meet the Government's requirements without the assistance of a leader company,

(iii) the assistance required of the leader company is limited to that which is essential to enable the follower company to produce the items, and

(iv) the Government reserves the right to approve contracts between the leader and follower companies.

[¶33,069]

4-703 Procedures.

(a) One procedure is to award a prime contract to an established source (leader company) in which the source is obligated to subcontract a designated portion of the total number of end items required to a specified subcontractor (follower company) and to assist the follower company in that production

(b) A second procedure is to award a prime contract to the leader company for the requisite assistance to the follower company, and another prime contract to the follower company for production of the items

(c) A third procedure is to award a prime contract to the follower company for the items under which the follower company is obligated to subcontract with a designated leader company for the requisite assistance

Figure 3. ASPR4-701 to 4-703 PROCEDURES

MIRCOM and the Air Force, if the follower fails to deliver an acceptable product, the leader company has defaulted its contractual obligations. It is uncertain whether the government's threat to withhold funds to the leader, if the follower fails to deliver, is credible. However, the Army has successfully used the technique to develop a second source for the production of the Shillelagh, TOW, and Dragon missiles. After the follower company passes first item tests, the progression to learning buys, split-award competition, and buy-out can progress as with the negotiated competition outlined above.

Cooperation of the leader company will probably be maximized by initiating the leader-follower agreement before the leader company is selected for the sole-source R&D production contracts. The leader-follower plan developed by each candidate would be one of the criteria, along with technical capability and cost, by which the winning firm is selected.

2. Fusion-Fission

A related technique dubbed "fusion-fission" is currently used by the Navy for the development and acquisition of the Airborne Self-Protection Jammer (ASPJ). Companies are required to form teams for the R&D phase. When the winning team is selected for production, the former partners become competitors for production contracts. The ASPJ program is presently in the R&D phase and the fusion-fission technique appears to be working. However, there are indications that companies would resist the use of this technique if practiced on a large scale.

3. Licensing

Finally, a licensing technique has been proposed to provide incentives to the original developer-producer for expediting

technology transfer.[1] Under this procedure, which has been used for patents in commercial markets, payment for technical assistance is made to the developer in two parts: a lump sum, plus a royalty, often five percent, for each item produced by the second source. To the extent that firms are more concerned with maintaining their production capability rather than with maximizing immediate profits, such a scheme would still be resisted by developers. However, it may be a useful technique for improving cooperation if the government makes a commitment to competition and technology transfer is required.

[1]Gregory A. Carter, *Directed Licensing: An Evaluation of a Proposed Technique for Reducing the Procurement Cost of Aircraft*, R-1604-PR, the RAND Corporation, Santa Monica, California, December 1974.

Chapter VI

PREVIOUS ESTIMATES OF SAVINGS DUE TO COMPETITION

While the use of price competition in the weapon system procurement process has been the subject of numerous studies and extended discussion in the past, the bulk of these analyses have made no systematic effort to interpret data from actual competitions. Indeed, our literature search has provided us with only three primary studies which have made widespread use of contract data in making their assessments. The methodologies and conclusions of these studies differ widely and the data bases contain virtually all of the presently available empirical information with which to study these questions; the estimates made in each of these studies regarding the cost savings from competition are discussed below.

A. A REVIEW OF THE COST EFFECTS OF SOLE SOURCE VS. COMPETITIVE PROCUREMENT BY THE COST ANALYSIS DIVISION, COMPTROLLER, U.S. ARMY ELECTRONICS COMMAND, FEBRUARY 1972

This study was the first and least sophisticated of the studies of the costs and benefits of competition. The 20 different systems listed in Table I.3 of Appendix I were included in the sample. Procurement of all of those systems is managed by the U.S. Army Electronics Command so the systems in the sample are more homogeneous and, on average, the unit prices are lower than those of the samples analyzed by the Institute for Defense Analyses [IDA] and the Army Procurement Research Office (APRO). The data are less well documented and no attempt is made to fit progress curves to the sole source production lots. Unit savings attributed to competition are estimated by

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comparing the unit price of the last sole source buy with the unit price of the first competitive buy. The method is illustrated in Figure 4 where a dashed line is drawn through the unit price. Savings in unit costs are equivalent to the vertical distance between the horizontal line and the plot of the unit cost of the first competitive buy.

The average savings in unit price for the twenty systems managed by ECOM is 56 percent. In contrast with the APRO and IDA method of projecting a price based on the sole source progress curve to compare with the competitive price, the ECOM method would be expected to overstate the savings attributable to competition. For 13 of the ECOM sample systems, sufficient data were available to fit progress curves and project a sole source price for comparison with the first competitive buy. The average unit savings estimated using progress curve projections is 53 percent. The rather small difference in the two average estimates results from the fact that the progress curves fitted to the sole source production lots have rather shallow slopes. Thus, the systems selected by ECOM appear to be exceptionally good candidates for the introduction of competition.

The balance of the ECOM study focused on an attempt to determine a predictive model or methodology which could relate causal factors to expected savings. However, no conclusive cause/effect relationships were found for the sample used.

B. REVIEW OF IDA STUDY S-249, "A QUANTITATIVE EXAMINATION OF COST-QUANTITY RELATIONSHIPS, COMPETITION DURING REPROCUREMENT, AND MILITARY VERSUS COMMERCIAL PRICES FOR THREE TYPES OF VEHICLES"

The IDA methodology for estimating savings was an improvement over that of ECOM but was less comprehensive than that of APRO. Documentation of the data was not as thorough, recurring costs were not separated from non-recurring costs, and prices

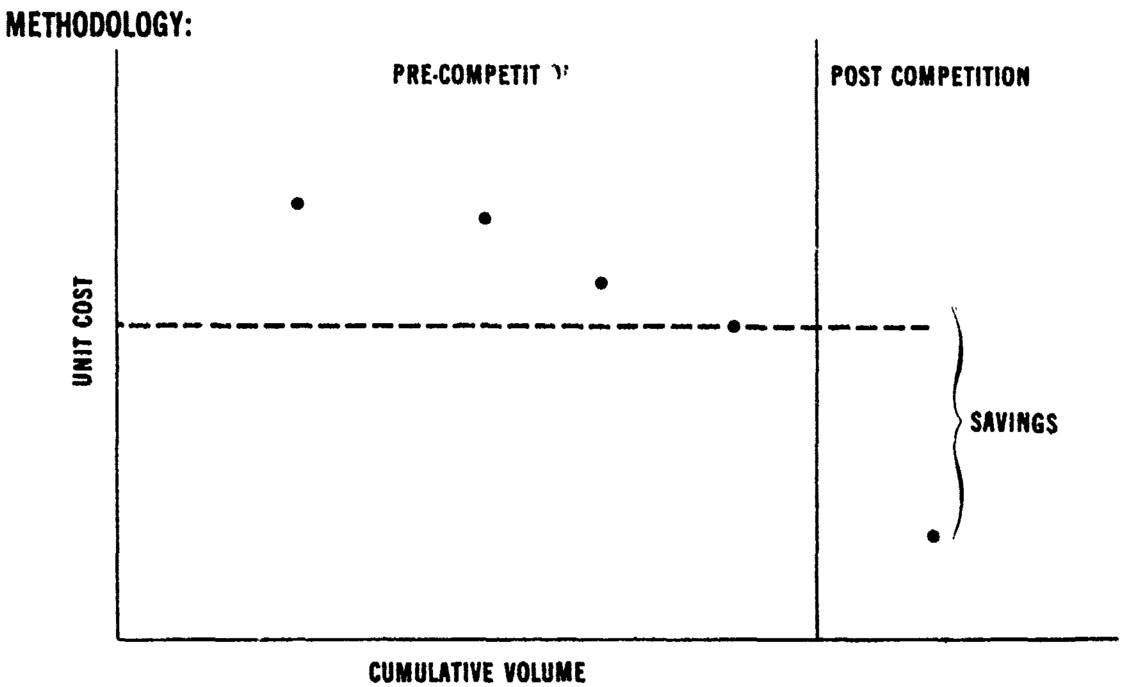

Figure 4. U.S. ARMY ELECTRONIC COMMAND METHOD

rather than costs were used to fit progress curves. As illustrated in Figure 5, a progress curve was fitted to the sole-source production data for each system. A projection of what the sole-source price would have been was made with the use of the progress curve. The vertical distance between the prediction and the actual unit cost of the first competitive buy estimates the savings in unit costs. No information on the costs of introducing competition were available and therefore were not incorporated into the estimates.

The average savings on the unit price of the first competitive buy is 37 percent for the nineteen systems examined by IDA and listed in Table I.2 of Appendix I. The range of estimates for the individual systems was from zero to 60 percent.

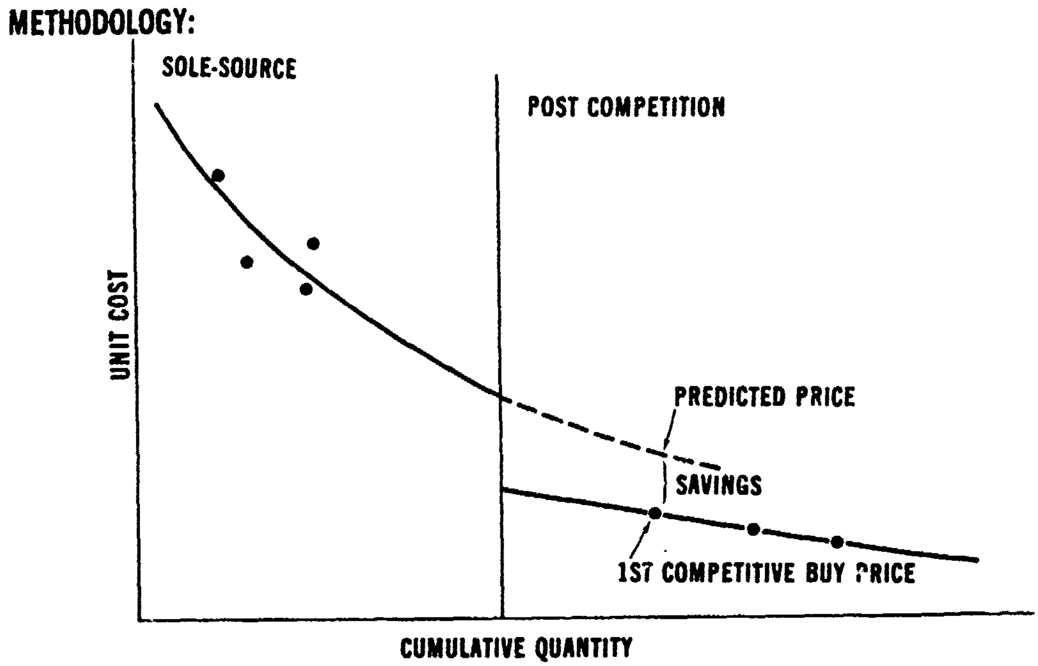

Figure 5. IDA STUDY METHOD

As with other studies, the sample cannot be assumed representative of all systems procured. This is emphasized by the fact that the original source won only one of the 20 competitions. Given the advantage gained by experience in the production of a particular system, that result would not be expected in a random sample of procurements.

The systems examined by IDA were almost all submitted in the formally advertised Invitation for Bid (IFB) style of competition with generally more than two bidders. That contrasts with several of the systems examined by APRO which frequently used negotiated competition between two contractors after a second source had been chosen and awarded an educational buy.

The IDA study involved more than the estimation of savings from the introduction of competition. By using regression analysis to explain variations between systems of savings on the first buy after competition was introduced, the following results were obtained:

- The flatter the sole-source progress curve, the greater the observed percentage savings.
- Winner-take-all competitions resulted in greater savings than competitions which split the award between two firms.

Another task of the IDA study was to compare the price of military noncombatant ships, aircraft, and wheeled vehicles with similar commercial vehicles. The results were:

- No significant difference was found between prices of military aircraft or wheeled vehicles when compared on the basis of vehicle empty weight; nor between commercial and military ships when prices were compared on the basis of useful load-carrying capacity.
- When compared on the basis of useful load-carrying capacity, military transport aircraft cost significantly less than commercial aircraft.

C. REVIEW OF REPORTS 709-3 AND TM-93 BY THE ARMY PROCUREMENT RESEARCH OFFICE AND TECOLOTE RESEARCH, INC.

The most sophisticated and well developed savings estimation methodology is presented in the study by the Army Procurement Research Organization (APRO), 1978. It is reviewed in greater detail in Appendix H. Briefly, all costs are converted to 1972 dollars; non-recurring and recurring production costs are separated and a progress curve is fitted to the data on sole-source recurring production costs. As illustrated in Figure 6, projections for all post-competition production costs are made with the progress curve and compared with actual post competition costs in order to determine gross savings on recurring production costs. Any extra non-recurring costs which result from introduction of competition are then

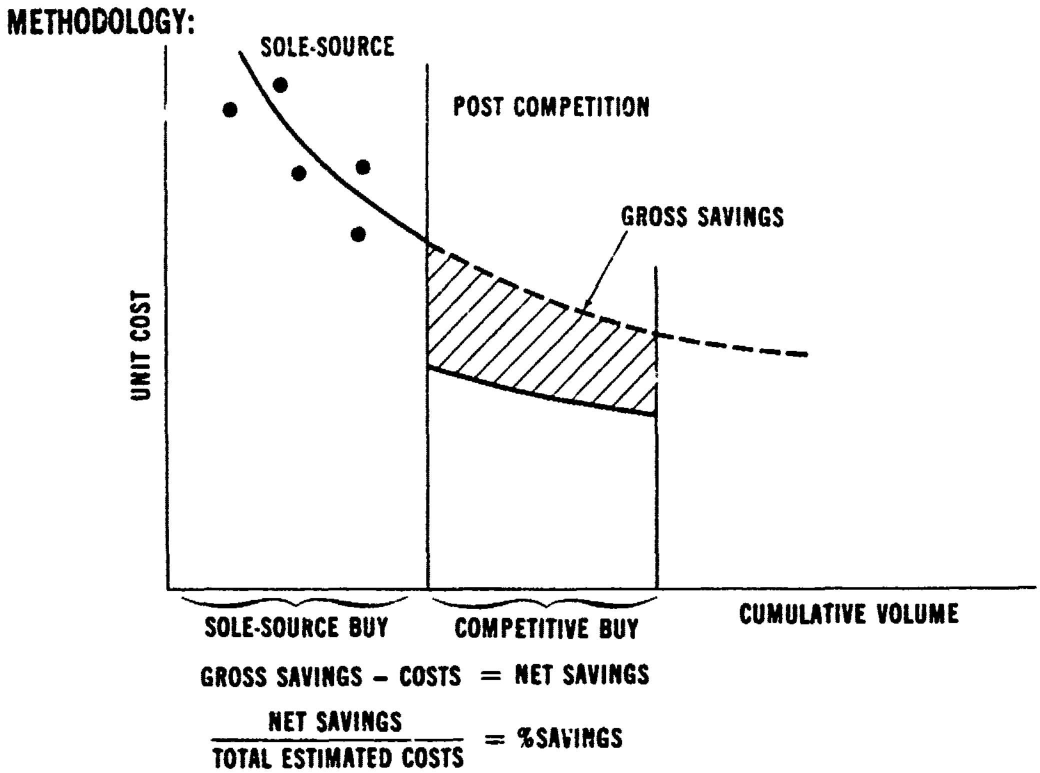

Figure 6. U.S. ARMY STUDY METHOD

subtracted in order to determine net savings. Net savings are then expressed as a percentage of what total program costs would have been if competition had not been introduced and sole-source procurement had been continued.

The systems examined in the APRO study are listed in Table I.1 of Appendix I. The average savings reported was 10 percent with a range of estimates from 53 percent for the Shrike Missile, to a loss of -81 percent for the Walleye Missile. The collection and description of data were, for the most part, excellent. However, extreme data manipulation and extrapolation were required to generate the estimates of savings. The critical separation of non-recurring and recurring costs was done on an unclear basis. Projection of sole-source costs for

post competition production required extrapolation of progress curves to ten or more times the sole-source quantities to which they were fitted. In several cases, progress curves were simply assumed or fitted to split-buy production lots which violates the spirit of the proposed savings estimation methodology.

Further, the definition of savings is misleading and inconsistent. By expressing savings as a percentage of total procurement, rather than post-competition production only, the estimates are made overly sensitive to the relative length of the sole-source production run and understate the savings to be expected on future unit production costs from introducing competition. Information on the fixed costs of introducing competition is incomplete for most of the systems so that application of the estimation methodology yields incomparable estimates of savings.

The sensitivity of the results to different methods of estimating progress curves and to the inclusion of different costs is illustrated in Table 2. Percentage savings for each system as estimated by APRO are presented in column one. The estimates in column two and column three follow the APRO methodology insofar as available fixed costs are used to determine savings and savings are expressed as a percentage of total program costs. However, the learning curve used to make the projections of the sole-source production costs for the estimates in column two were fitted with a weighted regression method. Instead of treating each production lot equally, as is done for the regression curve used in column one, the production lots are weighted in proportion to the size of the lots. Column three learning curves are estimated by using cumulative average price rather than average price of each production lot as the dependent variable. The progress curves for columns two and three were estimated using the only available data on sole-source production lots. However, APRO used

Table 2. DIFFERENT ESTIMATES OF PERCENT SAVINGS IN APRO SAMPLE

System	Overall Program-All Costs: APRO Unweighted Regression	Overall Program-All Costs: Weighted Regression	Overall Program-All Costs: Cumulative Average Learning Curve	All Post-Competition Production Recurring Costs Only	First Split Buy Recurring Costs Only	First Competitive Buy-Out Recurring Costs Only	First Competitive Buy As Calculated In the IDA Study
TOW Missile	8.5[a]	21.9[b]	5.4[b]	11.49[a] 20.77[b] 43.88[c]	3.01[b] 14.24[c]	31.75[b] 47.98[c]	48.1
TOW Launcher	30.2		39.2	35.00	None	43.47	
Dragon Round	2.7			4.78	d	19.22	
Tracker	12.0			18.99	d	59.17	
Standard Missile	-3.9	-4.12	-3.0	-5.83	None	-0.89	
Sidewinder Missile							
AIM 9B	-4.06	-10.31	-0.23	-5.28	-29.94	-14.40	
AIM 9D/G	-2.7	+14.94	-7.8	0.6	31.54	39.51	
Bullpup Missile	16.0	14.21	20.2	26.0	37.62	58.24	13.9 (Split buy) 45.8 (Buy out)
Walleye Missile	-21.4[e] -81.60[f]	e -81.82	e	e	e	e	
Shrike Missile	51.0			52.7	53.0	None	
Shillelagh Missile	5.9[g] -4.3[h]	-10.04[h]	-3.3	9.4 -4.0	-1.14 -14.0	22.42 -7.5	-0.2
FARR Radar	16.6	21.43		39.46 one buy	None	39.46	
FARR TADDS	18.2	22.68		31.13 one buy	None	31.13	
AN/PRC-77 Radio	34.8	30.35	7.85 to 10.9[i]	41.89	None	25.46	
ARC-131 Radio	-2.1[j]	-2.96		-16.07 award after default	None	-14.51	
AN/UPM-98 Test Set	3.0			11.54 one buy	None	11.54	

[a]APRO disaggregated the costs into prime contractor costs and subcontractor costs and then estimated two separate progress curves to make the projections used to estimate savings. A 95 percent progress curve slope was imposed on the subcontractor costs.

[b]One progress curve was fitted to the sum of the prime and subcontractor costs. No adjustements were made to the subcontractor costs.

[c]Separate progress curves were fitted to the prime and subcontractor costs. The subcontractor costs were not adjusted.

[d]Insufficient data.

[e]Not competitive.

[f]In calculating savings of -21.4 percent APRO made an arithmetic error. Correction of that number results in the estimate shown.

[g]Estimates on this line were derived on the basis of the sole source progress curve reported in the APRO study. However, the learning curve could not be validated. This number was used for all statistical summaries.

[h]Estimates on this line were based on our estimate of the progress curve using the APRO data.

[i]Percent savings depends on assumptions regarding payment of claims.

[j]Post competition contract was awarded sole source after the winner of the competition defaulted.

something other than sole-source production lots for ten of the eighteen systems analyzed.

For columns four through six, the progress curves as provided by APRO are used to derive the estimates except as specified otherwise in footnotes for the TOW Missile. The actual fixed costs incurred in introducing competition are neglected in calculating the estimates in these three columns; savings are calculated for recurring production costs only. Savings for each system are estimated for all post competition production in column four; the first split-buy competition awards in column five; and the first competitive buy-out award in column six.

Finally, the estimates of savings on the first competitive buy as reported in the IDA study (1974) are given in column seven for those systems which were included in both studies.

D. GENERAL ASSESSMENTS OF PREVIOUS STUDIES

The three studies present logical efforts to deal with difficult and complex problems. The methods of estimating savings differ and are insufficient for determining government policy. However, an estimate of expected savings on unit price (or, equivalently, recurring contract costs) as a result of competition is an important part of the decision criteria proposed in the next chapter.

As Table 3 illustrates, when the same method of estimating savings is applied to each sample, the results are roughly comparable. To recall definitions, the IDA methodology uses a progress curve projection to estimate savings on unit price of the first competitive buy only. The ECOM methodology compares unit price of the first competitive buy with the unit price of the previous sole-source buy; no progress curve projection is used.

Looking at each method of calculating and expressing savings for each sample, the average savings is positive although the

Table 3. COMPARISON OF DATA BASES--PERCENT SAVINGS

	APRO Method Overall Program Costs		All Post Competition Production	Difference of First Competitive Buy Price to Previous Price				Price Difference on First Competitive Buy Compared to Price Projected With Learning Curve			
	APRO-TECOLOTE 15 Systems	APRO[a] 10 Systems	Recurring Costs Only APRO and TECOLOTE 15 Systems	APRO[a,b] 10 Systems	IDA[c] 19 Systems	ECOM 21 Systems	ECOM[d] 1[illegible] Systems	APRO & TECOLOTE 14 Systems[e]	APRO[a,b] 10 Systems	IDA Study[c] 19 Systems	ECOM[d] 13 Systems
Median	9	9	12	37	45	59	59	26	26	42	58
Mean	11	13	15	30	47	54	59	28	26	37	53
Range	-13 to 51	-2 to 35	-17 to 53	-7 to 52	15 to 59	12 to 78	41 to 75	-15 to 43	-15 to 58	0 to 60	31 to 65

[a]Excludes systems analyzed by Tecolote.

[b]The first competitive bid refers to winner take all buy-out. The previous price frequently refers to a split-buy award. The numbers used could not all be verified.

[c]Includes split-buys and buy-outs.

[d]Excludes systems for which a progress furve could not be estimated.

[e]Excludes the AHRIKE Missile which had no buy-out, and the MK-46 torpedo because of analytical difficulties..

variation is substantial--especially in the APRO-TECOLOTE sample. The medians of the estimates using the ECOM methodology range from 37 to 59 percent; for the IDA methodology they range from 26 to 58 percent. Together, they indicate that the average system or component in each sample shows a positive savings in unit price after competition is introduced. In fact, all of the ECOM systems show positive savings and only one item in the IDA sample shows a loss. The APRO sample shows the most relative variation in savings and some of the least successful competitions (see Table 2). In evaluating the data it should be kept in mind that except for some of the APRO-TECOLOTE systems summarized in columns one and two, the estimates do not include any start-up costs.

We are forced to make inferences about the potential impact of introducing competition for the procurement of systems or components in the future on the basis of a sample which cannot be regarded as random and representative of the universe of weapon system procurements. Some systems were undoubtedly selected because they were regarded as good candidates. For other systems, in particular the ones examined by APRO and TECOLOTE which show negative savings, a second source appears to have been introduced at a time or in a manner which suggests that minimization of total system procurement costs was not the sole or even the primary objective (see Appendix H, pp. H6-H10).

Because the estimates of savings are based upon extrapolations of sole source progress curves, they are sensitive to changes in the parameters of those curves. The estimated savings for any particular system is therefore subject to considerable error. For the most part, we feel that where judgment was required, the estimates of progress curves were made in a conservative manner; i.e., with steeper slopes that tend to reduce the estimated savings. For the ECOM sample which included electronics and communications components only, the estimated sole-source progress curves have rather shallow slopes which result

in high estimates of savings. The progress curves are fit to actual, although limited, sole-source experience. The estimated slopes therefore reflect experience with those types of systems, or at least experience with the subset of systems selected for competition. Most of the ECOM systems would still show positive savings even if the progress curves' slopes were considerably steeper.

In spite of the problems mentioned above, we believe that the cumulative evidence of the three samples supports the conclusion that: substantial savings in procurement contract prices are possible as a result of price competition. Whether savings are realized, however, depends upon the selection of the system for competition and the timing, method, and cost of the competition introduced.

E. UNIFORM STATISTICAL ANALYSIS

Thirty one systems and components from the three previous studies were subjected to a more uniform statistical analysis. The items were included in the sample only if previous documentation was sufficient to allow the verification or re-estimation of the sole-source progress curve. A breakdown of the items by category, along with the average savings for each category, is shown on Table 4. Savings are calculated by subtracting the actual cost to the government (contract price) of all post sole-source production contracts from the price projected on the basis of the sole-source progress curve and then expressing the difference as a percentage of the projected sole source price. By that method the contract costs of learning buys for the second source and split-award competitions are included in the savings estimates along with the contract costs of the post buy-out competition production. Learning buys and, often, part of split-award competitions result in prices higher than those projected by the sole-source progress curve. The extra cost of these contracts represent part of the costs of initiating competition;

for the analysis presented in this section these costs, but not all start-up costs, are netted out against post-competition savings.

Table 4. DISTRIBUTION OF NET SAVINGS BY TYPE OF SYSTEM

Type of Systems Analyzed	Number	Net Savings On All Post Sole Source Buys (Includes Split-Award Savings)
Electronics and Communications Items	17	48%
Aircraft Components	3	41
Bomb	1	12
Torpedo	1	23
Missiles or Major Missile Subsystems	9	17
	31	35%

The sample must be considered biased in that the items were, for some reason, expected to benefit by the introduction of competition. Twenty-seven of the procurements, or 87 percent, showed savings through competitive procurement. Savings were not found to be dependent upon the unit price of the item.

Based upon the data available from the 31 procurements, a model was developed to forecast savings on future competitive buys.[1] It relates prospective savings to the previously observed sole-source learning curve slope and the size of the future, competitive buy relative to the size of the past sole-source buy. The model predicts that percent savings increase gradually with the quantity to be competitively procured, but that price reductions can still be expected on small quantities. It also predicts that savings are inversely related to the steepness of the prior sole-source progress curve slope; that is, if the

[1] See Appendix A for a more complete description of the analysis.

sole-source slope is steeper than 75 percent, zero or negative savings are expected.

As a group, electronics and communications items showed an average net savings on post sole-source contract prices of 43 percent in comparison with an average net savings of 17 percent for missiles and major missile components. There are at least three reasons for the difference. First, the estimated sole-source learning curves used to calculate the savings are, on average, steeper for the missiles than for the electronics and communications items. Whether the difference in slopes reflects a fundamental difference in underlying production technology and behavior or whether it is a statistical aberration of a small sample or inconsistent cost data is unknown. Second, the missiles, because they are more complex, require learning buys and split-award contracts before the second source obtains parity with the original producer. Learning buys awarded noncompetitively increase the cost of establishing a second source, and the related gross savings on unit price of split-award competitions is generally less than for all-or-nothing competitions. Therefore, as stated above, inclusion of such contracts tends to lower the estimates of net savings. For example, if calculation of savings is limited to the first competitive buy-out (winner-takes-all and no split-award competitions are included), the average savings on unit price for missiles increase to 27 percent.

Finally, the systems included in the sample with low realized savings might not have been selected for competition if the single purpose was to achieve a lower contract price. It is known that second sources for missile production are often introduced for reasons such as mobilization base expansion or because of technical or negotiation problems with the original source, rather than primarily to obtain lower contract prices.[1]

[1]See Appendix H, pp. H6-H10.

Chapter VII

PRICE COMPETITION AS INVESTMENT: A PROPOSED METHODOLOGY

A. INTRODUCTION

Ultimately, a decision has to be made regarding whether and when to initiate price competition during the weapon systems acquisition process. As we noted, practical considerations are almost certain to dictate that price competition, if it is to have a role, will have to occur during the reprocurement phase of the acquisition cycle.

The purpose of this chapter is to illuminate two basic points. First, the decision to utilize price competition is well suited for analysis within a cost/benefit framework. Second, the introduction of price competition has aspects of standard financial investments with substantial expenditures incurred at the beginning and benefits accruing with some uncertainty, over time. This has important implications for how such competitions, both past and prospective, should be evaluated. In particular, one should explicitly consider the net present value of cost changes produced by such competitions or, alternatively, should evaluate the internal rate of return achieved on resources devoted to initiating competition.

B. PREVIOUS STUDIES OF PRICE COMPETITION

The use of price competition to assign production contracts during reprocurement has not been widespread among the military services. The few instances where it has been utilized have been extensively analyzed by previous studies. We have made considerable use of the data bases assembled during the earlier

studies. However, we summarize the information embodied in those data in a different manner. The previous studies have placed considerable emphasis on statistics such as "reduction in system price following competition" (IDA, ECOM) or in "savings as a percent of total acquisition costs" (APRO, Tecolote). As noted in the preceding chapter, such statistics, while interesting, bear no necessary relationship to the cost-effectiveness of previous competitions because they fail to compare or, in some cases, even present the relevant costs and benefits which determine that cost-effectiveness.

C. PRICE-COMPETITIVE REPROCUREMENT AS AN INVESTMENT DECISION

Implementing price competition requires the actual or potential transfer of production capability and, most importantly, the associated technical knowledge between firms. Such transfers require the commitment of substantial resources to the process *prior* to the actual competition.

The primary objective of competition is, of course, the reduction of unit costs paid by the government for the item in question. Such a reduction in unit costs will hopefully result in lower acquisition expenditures by the government over the remainder of the planning horizon. The essential issue that must be confronted in considering the use of price competition during reprocurement is this: Will the reduced acquisition costs (if any) which result from price competition and which will occur over the entire planning horizon justify the initial expenditures which must be made to bring about that competition?

The fact that the time profiles of the benefits and costs of competition differ radically means that in making such a decision we must consider not only the magnitude of benefits and costs but also when they occur. In this sense the question shares fundamental similarities with investment decisions made by business firms. Typically, the firm is considering the

purchase of a piece of capital equipment which will enable expanding future output. Clearly, the firm must weigh a *stream* or *flow* of future benefits (in the form of the expanded output made possible by the capital equipment) and compare these to the current outlay required to purchase that equipment.

A business firm must have an *index* or *criteria* for use in making investments. That is, it must have some means for (a) ranking alternative investment projects and (b) deciding which projects to undertake, i.e., determining a "cutoff" point. Given the fundamental similarities involved and scarcity of funds, it is likewise desirable that DoD have a method of expressing the relative desirability of alternative investments in competition and of determining precisely which of those investments to undertake.

It is common practice among the financial planners of large corporations to measure the "internal rate of return" for investment projects. Such a statistic, in essence, reflects the productivity of each investment alternative. We propose to develop a similar measure for investments in price competition by DoD.

D. ESTIMATING THE INTERNAL RATE OF RETURN ON INVESTMENTS IN COMPETITION

A number of dimensions of physical output are likely to determine unit costs of production and, through them, the unit prices paid by the government. These "output" variables include cumulative or historical production (the so-called learning curve relationship); rate of output; the length of the planning horizon; and total planned volume.

Suppose that an acquisition plan or schedule exists, A(t), which describes for each point in time the quantities of a commodity that DoD plans to acquire. A hypothetical example of such a schedule is illustrated in Figure 7 in which the planned

rate of acquisition is measured on the vertical axis and time is measured on the horizontal. Figure 7 is drawn to reflect the characteristic pattern of peacetime weapon systems acquisition in which production is gradually built up to some planned long term rate.

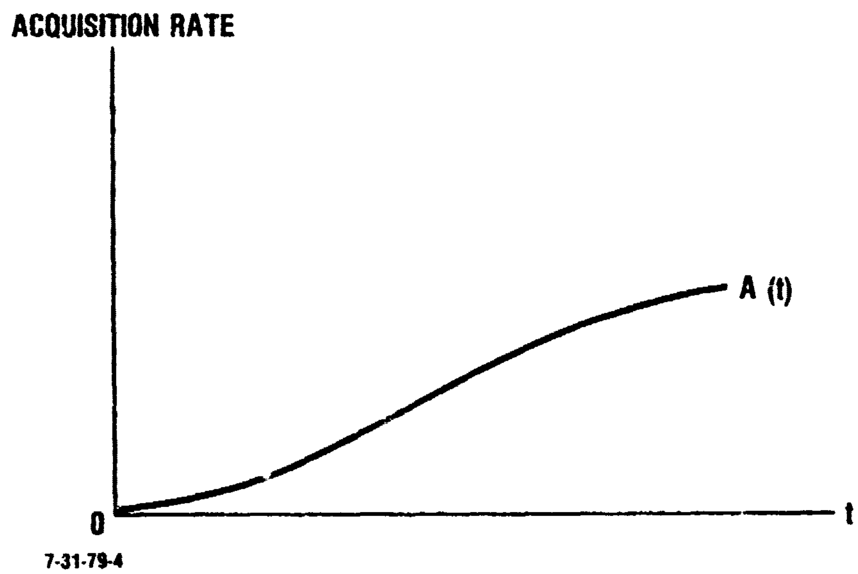

Figure 7. TIME PROFILE OF ACQUISITION

If both the acquisition schedule or time profile of Figure 7 and the cost-quantity relationships discussed above are known, the cost determining values of the output variables are specified. That is, given the acquisition schedule of Figure 7, we can determine a cost schedule, or profile, C(t), which represents the costs which are incurred by DoD over time in order to purchase the items at a rate indicated by A(t). Such a cost profile is shown in Figure 8.

Competition may be used to reduce the unit prices paid by the DoD during some periods. However, the expenditures

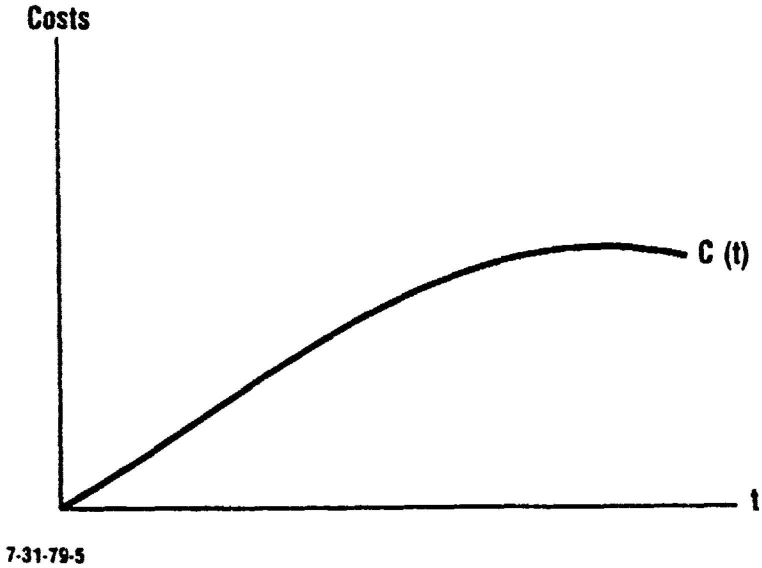

Figure 8. TIME PROFILE OF ACQUISITION COSTS

required to introduce competition imply a higher cost schedule during the initial periods than the schedule associated with non-competitive (sole source) procurement. These observations are illustrated in Figure 9 in which two cost schedules are shown. C(t), as before, is the non-competitive profile. C'(t) is the competitive profile. Initially it lies above C(t) (reflecting the costs of initiating competition), but thereafter lies below C(t) (indicating the reduced unit prices realized through competition).

In order to determine which of these cost profiles is preferable, DoD must explicitly account or adjust for the fact that the time distribution of costs differs in the two cases. That is, it must account for the "time value" or opportunity cost of resources. This is done by attaching a discount rate to expenditures to reflect the opportunity cost of resources used in this

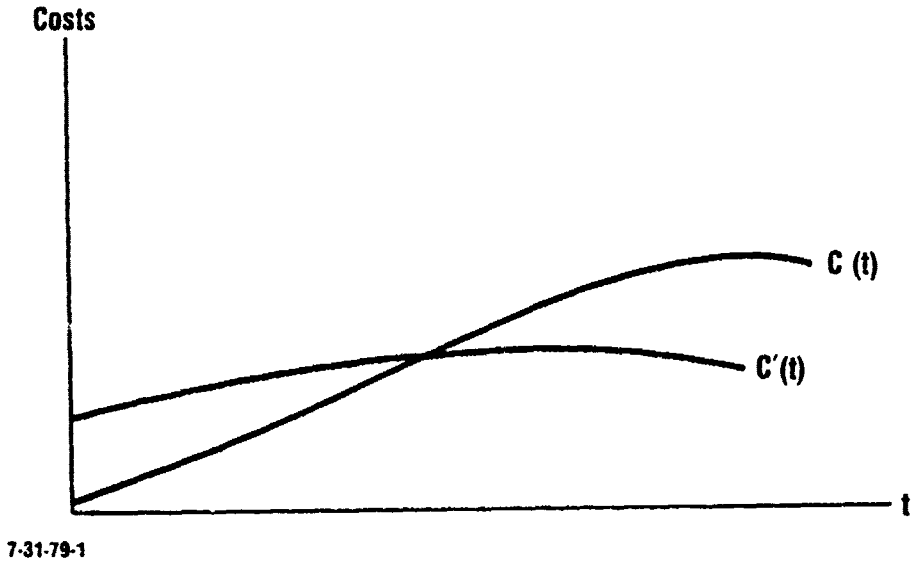

Figure 9. COMPETITIVE AND NON-COMPETITIVE COST PROFILES

process. Assuming that all costs are expressed in real terms (i.e., are deflated by the appropriate price indices), a rate of 10 percent is recommended by the Office of Management and Budget.[1]

Whatever the rate finally selected, the costs can then be expressed as present value equivalents. Analytically, this involves expressing each cost profile according to the following formula:

$$PV(C) = \int_{t_0}^{t_0+p} C(t)e^{-rt}dt \quad , \qquad (1)$$

[1]OMB Circular No. 4-94, March 1972, Office of Management and Budget.

where PV(C) is the present value of the cost profile, t_0 is the initial time, p is the length of the planning horizon, and r is the discount rate selected Efficient resource allocation requires that both cost profiles be so expressed and that competition be utilized when the present value of its cost profile is less than that of the non-competitive cost profile.

An alternative but conceptually equivalent approach may be more useful for certain decision-making purposes; it is to ask the following question: What is the rate of return earned on an "investment" in competition? To do this we treat r as a variable in expression (1) and ask: What value would r have to take in order to achieve the following equality:

$$\int_{t_0}^{t_0+p} C'(t)e^{-rt}dt = \int_{t_0}^{t_0+p} C(t)e^{-rt}dt \quad , \tag{2}$$

or

$$PV(C') = PV(C) \quad , \tag{2a}$$

that is, at what rate of discount will the present value of the two cost profiles be identical? The rate which brings about such an equality is called the internal rate of return associated with the particular use of competition. If this rate of return exceeds the opportunity cost of funds used by the government (again, the OMB recommendation is 10 percent), the investment in price competition is justified; otherwise it is not. In addition, such a rate of return can be used as a means of ranking projects in the order of their desirability.

Again, the critical factors can be illustrated graphically. In Figure 10 we subtract C(t) from C'(t) to derive the change in

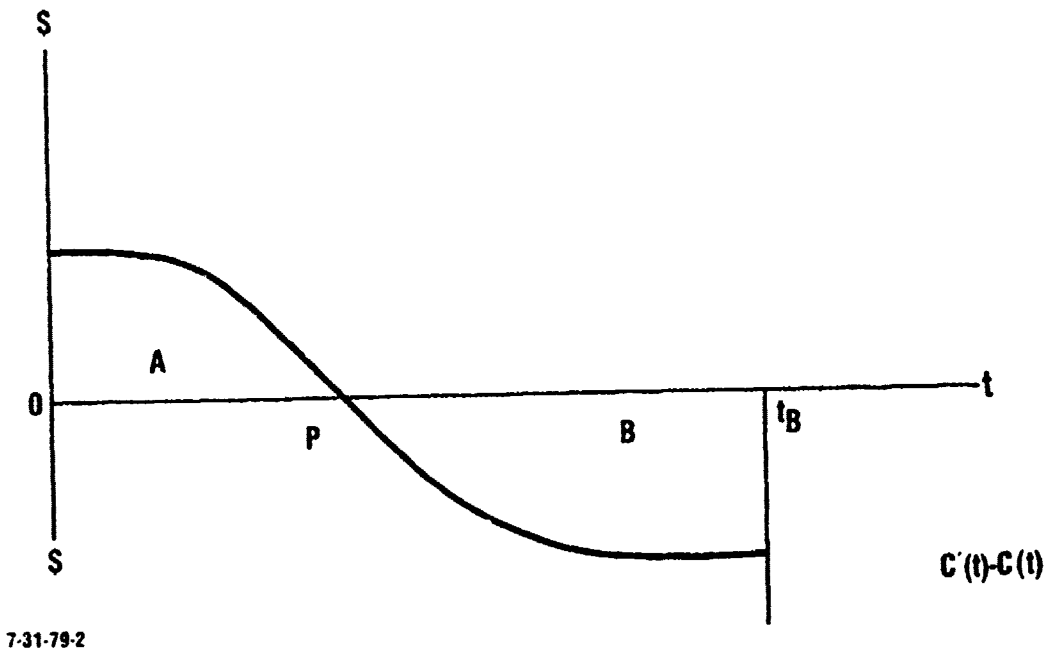

Figure 10. UNDISCOUNTED COSTS AND BENEFITS

the cost profile from introducing competition. As we can see, those changes are positive initially (due to the costs of initiating competition) and become negative thereafter. The internal rate of return is that discount rate which, when applied to this flow, makes its total value zero. Geometrically, this means that in Figure 11 the area beyond point p above the curve and below the axis must be equal to the area under the curve and below the axis prior to that point.

As illustrated in Figures 10 and 11, the fact that a competition ultimately results in a reduction in overall costs of acquisition does not mean that competition is necessarily desirable. That is, the present discounted value of the cost increases may exceed the present discounted value of the cost reductions due to the fact that the former occur early and are

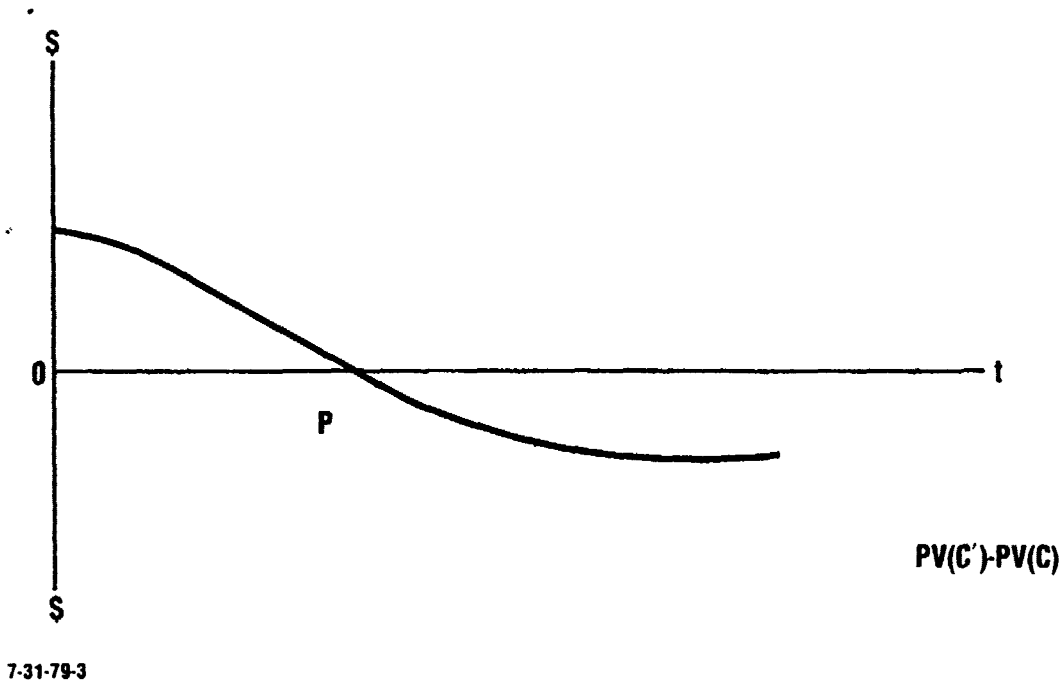

Figure 11. DISCOUNTED COSTS AND BENEFITS

discounted less than the cost reductions which occur later in the time horizon. Among other things, this demonstrates that the decision to utilize competition should *not* rest on some simple "break-even" analysis in which the algebraic sum of annual changes in costs are evaluated.

E. AN EXAMPLE: THE TOW MISSILE

The issues discussed above can be put into clearer perspective by an examination of an actual use of price competition. The system examined is the TOW missile. It was selected because it is illustrative of many aspects of the process and because of data availability.

1. Production History

The TOW missile was developed by the Hughes Aircraft Company. Hughes was also awarded the initial production contract in June 1968. During the same period, the U.S. Army Missile Command began actively searching for a second source. Chrysler was selected over Philco-Ford and Varo and in January, 1964 was awarded a contract for an educational buy with options for additional quantities. In April 1971 a split award competition was held: Hughes as low bidder received the larger quantity. Shortly after the award of these contracts, a buy-out competition was won by Hughes in December 1971. At that time production was projected to continue beyond 1980.

2. Cost Profiles

The TOW missile is a relatively complex system. As a result, the creation of a viable second source (Chrysler) to be used to compete with Hughes required not only a technical data package but also direct assistance from the system developer to aid in the process of technology transfer. The expenditures consisted of several components illustrated in Table 5 below:

Table 5. COSTS OF INITIATING COMPETITION

ITEM	COST (MILLIONS 1972 DOLLARS)
Non-recurring, Non-hardware Costs for 2nd Source	9.85
Contractual Support Paid to 1st Source	6.02
Post Competition Non-recurring Costs	5.66
Learning Buy of 200	2.30
TOTAL FIXED COSTS	23.83

Source: Lovett, Edward, *Impact of Competing Previously Sole Source/Non-Competitive Contracts*, U.S. Army Procurement Research Office, APRO-709-1, Fort Lee, Virginia, March 1978.

As observed in earlier examinations of the TOW missile acquisition, the buy-out resulted in a sharp reduction in unit prices. APRO attempted to compare the post competition unit prices with those predicted by the extrapolation of the sole-source progress curve. We have allocated the total projected post-competition reduction in contract costs in proportion to the quantity produced each year. This cost savings profile is illustrated in Table 6. The cost profile of the competition thus reflects the classic characteristic of a business investment decision: A substantial, essentially fixed initial outlay of over $23 million in return for the stream of cost reductions shown in Table 6.

Table 6. PROJECTED COST REDUCTIONS DUE TO COMPETITION

	MILLIONS OF 1972 DOLLARS		
YEAR	UNDISCOUNTED	DISCOUNTED AT 10%	DISCOUNTED AT 24.2%
1972	5.38	4.45	3.49
1973	9.84	7.39	5.13
1974	6.84	4.71	2.90
1975	15.93	9.89	5.39
1976	16.08	9.08	4.38
1977	5.96	3.06	1.31
1978-83*	1.90	0.71	0.21
TOTAL	71.43	42.81	23.86

*projected annual average

Source: Lovett, Edward, *Impact of Competing Previously Sole Source/Non-Competitive Contracts,* U.S. Army Procurement Research Office, APRO-709-1, Fort Lee, Virginia, March 1978.

Several aspects of the financial impact of introducing competition should be observed. The total cost reductions achieved ($71.43 million) substantially exceed the initial

outlay of $23 million when discounting is ignored. The use of discounting, i.e., the assumption that there is a "time value" of money, substantially reduces the magnitude of those benefits. The second column of Table 6 lists the expected future savings discounted at 10 percent. Subtracting the start-up costs of $23.83 million from the total discounted savings yields an estimated net discounted value (NPDV) of $18.62 million. The third column shows the annual savings discounted at 24.2 percent. The approximate equality of the total discounted future savings with the start-up costs implies that the estimated internal rate of return is 24.2 percent.

Although the absolute value of the net benefits of competition are substantial, even when discounting at 10 percent, the "break-even" or "payback" point is not achieved until four or more years have elapsed from the date of initial expenditure. Put differently, even when price-competitive reprocurement policies turn out to be good investments, they do not produce a quick or instantaneous recouping of initial outlays.

The issue of just how productive the TOW missile price competition was is important. Using the OMB specified discount rate of 10 percent, the calculated NPDV is positive. Likewise, the calculated internal rate of return of 24.2 percent is substantially greater than the 10 percent opportunity cost of government funds. By both criteria, we conclude that the TOW missile price competition was highly cost-effective.

Chapter VIII

STRUCTURE OF THE ANALYSIS OF THE IMPACT OF COMPETITION

A. INTRODUCTION

The decision to compete or not to compete a particular system or subcomponent should be supported by a careful analysis of costs, expected price reductions, and non-price effects. The data for such an analysis are necessarily estimates of future prices and quantities and the expected response and performance of contractors. A great deal of uncertainty is therefore involved; substantial variation between estimates and realized values may occur for particular systems.

The limited experience with competition for production contracts and the variety of special circumstances surrounding the procurement of each system prohibit the development of systematic relationships between system characteristics and expected savings from introducing competition. However, a structure for analysis of the decision to introduce competition can be offered, and the average experience with previous procurements can be used as a forecast of expected gross savings in unit prices.

Cooperation is required of personnel in the pricing, contracting, and program management offices of the various material commands within the Armed Services. There exists the information on previous contracts and familiarity with the procurement of similar systems, alternative contractors, and industry conditions.

However, perhaps the Office of the Secretary of Defense (OSD) will wish to specify certain parameter values and

assumptions which underly the analysis. By so doing, the OSD implicitly accepts more of the responsibility for the decision to compete, and the required judgments can reflect broader experience than provided by a single procurement office.

This chapter consists of an outline of the type of analysis required whenever the introduction of competition is considered for the procurement of a particular system. Where possible, parameter values or working assumptions are suggested when there is some basis for them. In Appendix F, a series of stylized numerical examples are presented which illustrate the sensitivity of the projected savings with respect to how soon the second source's production is initiated, whether the second source reaches production cost parity, and the speed with which the production schedule is built up.

B. NON-PRICE ASPECTS

While this chapter primarily concentrates on the estimation of net savings from introducing competition, thorough analyses must consider the impact of competition on non-price aspects of procurement as well. Those aspects include:

(1) The technical performance of the present contractor and the reliability of the system, compared with that expected from a new source;

(2) Potential for defaults and delays in delivery;

(3) Logistics and maintenance cost increases if the new source does not produce an identical copy;

(4) The viability of the industrial base--

- Entry and exit of firms
- Mobilization surge capacity.

Although difficult or impossible to quantify, the non-price effects of competition may support or be sufficient to overturn a decision based upon the estimate of net savings alone.

C. NET SAVINGS

Net savings depend upon start-up costs, the volume of production subject to competition, and the expected reduction of unit price. Estimates of annual net costs or net savings should be converted to constant year dollars to adjust for inflation and for ease of comparison. The annual flow of costs and savings should be summarized by calculating the net present discounted value or the rate of return. A brief discussion of each aspect of the forecast of net savings follows.

1. Start-Up Costs

Start-up costs may be incurred for any or all of the following categories.

(1) Selection of the second source
(2) Cost of technology transfer
  (a) Technical data package
  (b) Technical assistance
  (c) Rights in data
  (d) Engineering services contract for maintenance of TDP
(3) Special tooling and test equipment
(4) Production of first articles
(5) First article testing
(6) Extra cost of learning buys

The complexity of the system determines the sophistication of the technique required to introduce a new source and transfer the requisite technology, the extent of first article testing, and the volume of learning buys required by the second source to roughly attain production-cost parity with the first producer. The cost of acquiring the TDP and technical assistance from the original producer-developer should be negotiated before competition is actually introduced. Estimates of tooling, testing, and production costs for the second source could reasonably be based

on those of the original producer. We do not have sufficient information to verify an assertion by a cost analyst that the costs of special tooling and test equipment provided to a second source is about 80 percent of the cost incurred for the original source. Competition, however, may be expected to keep such start-up costs lower than those incurred by a sole source.

It should be emphasized that only the extra tooling, testing, and production costs should be attributed to competition--the difference between projected costs of procuring a number of items from two sources and the projected costs of producing the same number of items in a sole-source environment. Because the estimates of start-up costs are based on experience with the initial source and are incurred relatively early in the procurement cycle, they should be relatively accurate as compared to the estimates of volume and savings in unit price.

The OSD may wish to constrain the estimates of the start-up costs with respect to:

(1) When the second source can be expected to begin production;

(2) The cost of initial production by the second source relative to the experience of the original producer;

(3) The volume of production required by the second source to gain production cost parity with the original producer.

Usually the technical data package (TDP) must be validated by volume production, prepared by the original source, and then examined for errors by the government or an independent third party before it is used for selection of a second source and transfer of technology. If competition is considered early, some form of leader-follower procurement which provides for direct technical assistance from the leader company to the follower may be feasible. Relative to using a validated TDP to initiate competition, use of leader-follower could save as much as two years of lead time required to establish a second source

Such a reduction is possible if the second source can be selected before the TDP is validated by volume production and if direct technical assistance can supplement an incomplete TDP for the transfer of technology.

Experience with the procurement of four missiles and missile guidance and control systems indicates that the second source requires only a fraction of the volume produced by the original source to reach production cost parity. Table 7 summarizes the experience with the four missiles; on average the second source required only 23 percent of the volume produced by the first source in order to gain production parity. After the quantities indicated were produced, the unit price of production was approximately equal for both producers, or the second source managed to win the competition for the next production contract.

These figures are not fixed and should be taken as indicative only. Some items, competed by the formal IFB method, require no precompetition production; for other systems the second source never wins a competitive award. In general, however, it is more likely that the second source will begin producing at a lower first unit cost and progress down its learning curve more rapidly than the original source. Some transfer of learning and the pressure of competition account for the expected difference. The impact of assuming production cost parity is examined in the numerical examples presented in Appendix F.

2. Volume Subject to Competition

Planning for competition should consider all expected future requirements, not just the next year's quantity. Requirements of all Services should be included with those of the Service executing the procurement, and the impact of foreign military sales on price and on expected savings on government buys should be considered.

Table 7. QUANTITIES REQUIRED FOR SECOND SOURCE TO REACH PRODUCTION COST PARITY

SYSTEM	CUMULATIVE VOLUME (1) FIRST SOURCE	CUMULATIVE VOLUME (2) SECOND SOURCE	RATIO (2)/(1)
BULLPUP	37,032	4,438	12%
SHILLELAGH	17,945	4,960	28%
TOW	11,168	2,685	24%
SPARROW	4,313	1,255	29%
AVERAGE			23%

59793

There is an understandable tendency to be conservative in the projection of future requirements, requirements of other Services, and of foreign military sales. The commitments to those numbers are not firm and are subject to reduction for any number of reasons such as budget reductions, completed development of superior systems, and altered threat assessment. Use of best estimates of future requirements rather than conservatively low estimates is to be preferred for the evaluation of the impact of competition. Unrealistically low estimates of future requirements bias against the decision to introduce competition. Missed opportunities for savings by waiting too long can be as costly as introducing a second source and then realizing an unforeseen drop in requirements.

3. Reduction in Unit Cost

The reduction in unit cost is the most difficult component to forecast. It is in fact likely that no precise and stable predictive relationship exists; there are so many dimensions of variation surrounding each procurement (e.g., technology, market conditions) that each system is to a considerable extent unique.

Experience with previous systems reveals considerable variation in the realized gross savings in unit prices after competition. A brief summary includes the following information:

For Split-Award Competition:

- On six previously procured systems, the average savings on the first split award was 12 percent;[1]
- For the Sparrow AIM-7F guidance and control system, the savings are 12 percent the first year, 16 percent the second year, and 27 percent the third year.[2]

[1]See Table 2, page 56 of this report.

[2]Appendix B of this paper.

For Winner-Take-All Competition:[1]

- On 17 electronics and communications items for which IFB competition was used, the average savings was 48 percent;
- On 9 missiles or major missile subcomponents, the average savings on the first winner-take-all award was 27 percent.

Based upon this information, reasonable, yet conservative figures for the projection of post competition savings are 10 percent for split-award buys and 20 percent for winner-take-all buy outs. These numbers can, of course, be adjusted to incorporate information regarding the circumstances surrounding the procurement of a particular system. The general level of excess capacity and the availability of alternative contractors, which will vary by industry, weapon system, and perceived performance of the original contractor, should impact the level of the bids submitted. The full effect of those factors will only be revealed when the bids are actually submitted, but sufficient *a priori* information may be available to adjust the expected savings rate up or down.

If available when competition is being evaluated, the actual production experience of the present producer may be incorporated in the projection. Actual or proposed costs of the contractor greater than government estimates or a relatively flat progress curve suggests relatively greater savings from introducing competition. Problems of delay and defaults and general contractor intransigence, as well as providing a reason to consider the selection of a new source, may also suggest an adjustment to the average projected savings. Of course, the delivery problem may be at least partly a result of a contract price which is too low. Competitive source selection may then yield a higher rather than a lower price.

[1]Refer to Table 4, Chapter VI.

4. Net Present Discounted Value and the Rate of Return

The costs and benefits evaluated on an annual basis should be converted to constant year dollars in order to facilitate comparisons. Insofar as we have been able to determine, it is the practice of personnel in the material commands to sum the annual figures to determine the projected savings, the break-even point, and simultaneously, the pay-back period for the initial front-end expenditures. Such a summation is an incomplete and misleading statistic because it fails to consider the pattern of costs and benefits over time and the opportunity cost of funds.

The appropriate procedure requires discounting of all future annual increases or decreases in costs by the appropriate opportunity cost of funds in order to determine the net discounted present value (NPDV) of introducing competition, or computation of the rate of return.[1]

The procedure is illustrated in the case study of the Guidance and Control section of the Sparrow AIM-7F missile in Appendix B. The general equation for the NPDV is:

$$NPDV = B + \frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + \ldots + \frac{B_{n-1}}{(1+r)^{n-1}} + \frac{B_n}{(1+r)^n}$$

where

B_i = the extra costs (negative) or extra savings (positive) incurred in the period i as a result of introducing competition. The subscript runs from 0 for the base year to n which stands for the last year in which competition has an impact on savings

r = the appropriate discount rate--the opportunity cost of government funds.

[1] See Mishan, E.J., "Cost Benefit Analysis," Praeger Publishers, New York, 1976; Van Horne, James C., "Financial Management and Policy," Prentice Hall Inc., Englewood Cliffs, New Jersey, 1974; or similar texts.

For the AIM-7F the NPDV equation is:

$$NPDV = -2.1 - \frac{30.6}{(1+r)^2} - \frac{3.4}{(1+r)^3} - \frac{4.7}{(1+r)^4} - \frac{27.1}{(1+r)^5} + \frac{15.0}{(1+r)^6}$$

$$+ \frac{30.5}{(1+r)^7} + \frac{50.4}{(1+r)^8} + \frac{15.6}{(1+r)^9} .$$

The discount rate r, which, when applied to the stream of costs and benefits, equates the NPDV to zero is known as the rate of return. For the AIM-7F example, the rate of return is 0.12 or twelve percent.

Two alternative financial decision rules are:

(1) Make the investment if NPDV > 0 when the discount rate is equal to the opportunity cost of government funds; or

(2) Make the investment if the calculated rate of return (which equates NPDV = 0) is greater than the opportunity cost of government funds.

The decision rules are equivalent as long as all net costs (negative benefits) precede all net savings (positive benefits) in the time stream. That will generally be the case when the investment under consideration is the introduction of competition.

Although the financial aspects of the evaluation of the impact of competition are well summarized by the NPDV or the rate of return, they may be insufficient to determine whether competition should be introduced for reprocurement of a particular system. As stated above, the impact of competition on non-price, occasionally unquantifiable, aspects of procurement must be considered. They may be sufficient to counter decisions based upon financial estimates alone.

Chapter IX

CONCLUSIONS BASED UPON EMPIRICAL ANALYSES AND QUALITATIVE FINDINGS

A. CONCLUSIONS BASED UPON EMPIRICAL ANALYSES

Based upon the analysis of the data on previous price competitions for production contracts, the following tentative conclusions express our perspectives on the role of price competition:

The introduction of competition is an investment and it should be evaluated accordingly. Calculation of the internal rate of return (yield) to investment in competition summarizes the effects of initial start-up costs, savings on unit production costs and volume and time distribution of post-competition production in one number. The internal rate of return or net present value can then be compared more easily than those of other opportunities for the investment of government funds.

While previous examples of price competition show mixed results, they appear on average to have represented cost-effective investments of scarce resources. The eventual savings on production costs have more than recovered the costs of initiating competition. This appears to be particularly true of those competitions whose primary purpose was the reduction of system price.

Although previous competitions appear to have been good investments, the initial costs incurred in holding them for major weapon systems may not be recouped until three or four years of production are completed. This has an important and

seldom noticed implication: While the expanded use of price competition for major system procurement will reduce DoD costs in the long run, it will almost certainly raise them in the short run. Such competition should be employed as part of a coherent long run strategy and not as an attempt to produce savings in a current period.

Systems which display flat sole-source progress curves and for which significant future requirements are anticipated are prime candidates for competition. Other criteria for selection remain to be determined.

In terms of reduction in system price for a particular contract, competitive buy-outs where the winner receives the whole contract produce greater savings than do competitions which split the awards between two firms. However, other considerations may frequently justify the use of split-buy competition.

Delivery delays have been significant for some systems. In particular the use of formal advertising often results in the award of a contract to a low bidder who is inexperienced and incapable of delivery. This problem may be accentuated if awards are set aside for small and minority owned businesses or for labor surplus areas.

Widespread use of price competition may raise costs of earlier phases of the weapons systems acquisition process. Firms would no longer have an incentive to buy-in during the R&D phase in anticipation of higher profits during the production phase.

B. QUALITATIVE FINDINGS

As part of our effort to determine criteria for the selection of systems for the introduction of competition, we attempted to determine the following with respect to competitive reprocurement:

(1) How candidate systems are presently selected;

(2) The types of problems frequently associated with the introduction of competition;

(3) System characteristics or other conditions which inhibit the use of competition;

(4) Perceptions of the benefits of and attitudes toward the desirability of more price-competitive procurements.

Information on these subjects was obtained by interviews with personnel in the material commands involved with the procurement of weapon systems. The issues covered include:

(1) Program stretchouts

(2) Cost of initiating competition

(3) Risks of delays, defaults, and reduced reliability

(4) Technical data problems

(5) Inability to use multi-year contracts

(6) Inadequate incentives

(7) Non-price benefits of competition

(8) Alternatives to pure price competition

(9) Competitive reprocurement and design to cost, design to life-cycle cost, and reliability improvement warranty programs

(10) The need for flexibility.

Although each of these issues is discussed separately in Appendix G, they are interdependent. For example, the risks involved are partly a function of technical data inadequacies. But technical data problems and other risks incumbent in competition can be reduced with increased start-up expenditures, thorough validation of the technical data package, and careful qualification of the second source. Appendix G presents a distillation of our impressions gleaned from examination of previous case studies, a review of the literature from the interviews; it is not merely a verbatim report of our discussions.

The major findings of this study can be summarized as follows:

(1) Competitive reprocurement will not be introduced to all systems and components for which it is feasible under present policies and practices. Reasons include adverse incentives and attitudes toward incurring the initial cost and toward the risk of delay for the chance at a future reduction in system price; constraints on funds and personnel required for the initiation of competition; and procurement regulations which tend to restrict choice of competitive techniques.

(2) There is a tendency to use formally advertized competition more often than is appropriate. It is faster, costs less, and makes available more procurements for small businesses. However, it is risky, especially when the specifications are not firm and the technical data package is inadequate. Once an exception to formally advertised competition is obtained for a particular procurement, other methods of initiating competition are not routinely considered.

(3) Early planning can reduce costs and delays required to effect transfer of technology and can increase the actual production volume subject to competition.

(4) Non-price aspects of competition are significant and may be the deciding factor for or against the introduction of competition. Inadequate technical performance of the original producer, fear of reduced reliability or delivery delays, the impact on the industrial base, and the impact on logistics and maintenance costs have all been deciding factors.

(5) Production to form, fit and function, and performance specifications may ease the burden of technology transfer and be an attractive alternative to pure price competition.

Chapter X

RECOMMENDATIONS

This chapter presents recommendations for the use of competitive procurement based upon the analyses of previous procurements, interviews, and case studies. In Section A the financial criteria presented previously are reviewed, and an additional, but equivalent, criterion is presented which may improve the communications of the OSD with the material commands of the Services (who are charged with the actual procurement of systems and equipment). Also included is a list of three different situations which identify a system or component as a price candidate for the introduction of competition.

Section B addresses the decision of how long to maintain multiple sources so that annual procurement requirements can continue to be awarded competitively. The feasibility and relative merits of continuous IFB competitions, a winner-take-all competition for a multi-year contract, and continuing split-award competition are discussed. Section C discusses several changes in policy and practice suggested to facilitate the appropriate use of competitive procurement.

A. THE DECISION TO INTRODUCE COMPETITION

The decision to introduce competition has many aspects of a financial investment and should be evaluated as such. We have addressed the problem of estimating the annual changes in costs which result from the introduction of competition and have presented two equivalent financial decision rules:

(1) Introduce competition if the net present discounted value of the annual changes in cost are greater than zero.

(2) Introduce competition if the rate of return is greater than the opportunity cost of government funds.

Both decision rules presume that estimates of the annual increments to costs are available. Frequently, however, the information available at the level of the OSD, relative to that of the Service, may be less adequate for estimating start-up costs than it is for estimating eventual annual savings. If that situation exists, it may be desirable to cast the decision rule in a slightly different form. Basically, the annual post-competitive gross savings are discounted by the opportunity cost of government funds. This provides a ceiling on acceptable start-up costs which can be presented to the material commands of the Services along with the instructions to:

(3) Introduce competition if the estimated start-up costs are less than the discounted savings.

The decision rule can be illustrated more precisely as follows. Suppose that savings are projected to begin in the third year after the first start-up costs are incurred and savings continue until the nth year. Then the discounted gross savings (DS) are

$$DS = \frac{B_3}{(1+r)^3} + \frac{B_4}{(1+r)^4} + \ldots + \frac{B_{n-1}}{(1+r)^{n-1}} + \frac{B_n}{(1+r)^n} , \qquad (1)$$

where the B_is are the annual savings (all positive) and r is the opportunity cost of government funds.

By definition, the net discounted present value (NPDV) is

$$NPDV = B_0 + \frac{B_1}{(1+r)} + \frac{B_2}{(1+r)^2} + DS \qquad (2)$$

The financial criterion, NPDV > 0, is easily shown to be equivalent to the following:

$$DS > -B_0 - \frac{B_1}{(1+r)} - \frac{B_2}{(1+r)} \quad , \qquad (3)$$

where the estimates of annual start-up costs B_0, B_1, and B_2 are negative, so that the sum on the right of the inequality is positive. If the estimates of annual start-up costs are compatible with the equation (3), then competition should be introduced unless non-price considerations override the financial criterion.

Use of the third form of the decision rule allows the OSD to incorporate their own assumptions into the estimation of gross savings and rely on personnel of the Services for estimating start-up costs. Again, the OSD may decide to specify some of the assumptions used to estimate start-up costs such as how soon the second source initiates production, how its initial production costs compare with those of the original source, and the volume of production required by the second source in order to gain production cost parity. Such specifications should be made in order to relieve the individual project management offices of some of the responsibility for the risk of delays and defaults incumbent with the introduction of competition and to provide a basis for more uniformity in the analysis of different systems. The individual program management and contracting offices will always be more familiar with the details surrounding the procurement of a particular system. Their opinions should be considered in the evaluation of the impact of competition; their cooperation is indispensable.

The findings of this study reveal three different situations which identify a particular weapon system or component as a prime candidate for the introduction of competition. They are listed and briefly discussed as follows.

1. The Expected Reduction in Production Costs Outweighs the Costs of Introducing Competition

This is simply the situation when the estimated net savings satisfy one of the financial criteria presented above. The cost analysis should, however, be supplemented by at least a preliminary analysis of the impact on non-price aspects. Procurement personnel with experience on similar systems should determine whether capable alternative contractors are available and willing to bid; whether the impact on the industrial base is likely to be adverse; and whether the risk of defaults or delays in delivery is acceptable or can be avoided by the use of a sophisticated competitive technique.

2. Difficulties with the Present Contractor and Substantial Volume Left to Produce

Schedule, delivery, product quality and price difficulties with the original sole-source contractor have often motivated the introduction of competition for reprocurement of systems. Introducing competition has the salutary effect of either introducing a more technically competent contractor, or motivating the original contractor to apply qualified personnel to the effort required to solve the problems. Difficulties may be manifested by failure to pass qualification tests; delays in delivery; costs higher than government estimates or flat progress curves; or a general intransigence on the part of the contractor with respect to contract negotiations and response to government requests. It should be emphasized that in this situation, competition will not necessarily reduce system price. In fact, too low a contract price may be part of the reason for the production problems. Rather, the expected benefit of competition in this situation is primarily the resolution of the problems of unsatisfactory contractor performance.

3. Industrial (Mobilization) Base Expansion or Maintenance Is Desired

When the procurement requirements are such that the planned production rate is a substantial share of one firm's capacity, or when an all-or-nothing award may drive unsuccessful competitors out of a vital defense industry, it may be desirable to spread production between two or more firms. Such allocation tends to reduce the risk of delivery interruptions and increase the war time surge capacity.

The splitting of production awards may be especially desirable if the total desired production rate would require expansion of one firm's capacity while other firms have excess capacity available. If substantial commercial applications of the item procured by the government are anticipated, it may be desirable to increase the number of available sources immediately in order to ensure supply and to avoid the establishment of a monopolist with a lucrative alternative to government contracts.

Although production could be spread among contractors by the use of non-competitive negotiated contracts, competition can be expected to result in lower prices. Competition, with production shares awarded in inverse relation to price, is probably the most equitable and efficient way to allocate production contracts among firms with excess capacity. Such split buys will not necessarily achieve the price savings attainable through all-or-nothing competitions, but when it is essential to avoid the exit of any firms from a particular subset of the defense industry, the use of price competition must be restricted.

B. THE DECISION TO CONTINUE COMPETITION

Maximum benefits are obtained when as much of the procurement volume as possible is submitted to competitive award. However, the inability to foresee all future requirements, the

unavailability of funds, or a specific need for periodic procurement may render unfeasible a one-time competitive buy-out, and substantial requirements may remain to be fulfilled after the first competitive reprocurement. Much of the advantage of competition is lost if it is used just once in order to select a contractor who thereafter becomes a *de facto* sole source, and receives all follow-on contracts on a negotiated basis. (Examples indicate that constant-dollar unit prices occasionally rise under such circumstances.) Such one-shot competitions may be of some benefit to the government, but they encourage a strategy of "buy in and get well later" which could have adverse impact on performance and on future contract negotiations.

The decision to repeat competition is similar to the decision to introduce competition initially and similar to the choice of technique to establish a second source. No single method can be used to repeat competition for all systems, and no simple formulas can be advanced to choose between the strategies described below. However, the advantages and disadvantages of each method can be presented in order to clarify the choice.

1. Periodic IFB Competition for Winner-Take-All Award

Where appropriate, a formally advertised competition is often the easiest and cheapest way to maintain competition. However, for complex items a simple one- or two-step IFB competition may not be acceptable. Even when an IFB competition is technically feasible, periodic invitations for bids from new sources, who are inexperienced with the system, increase the costs of evaluating new firms and the risks of delay and diminished reliability often associated with the transfer of technology to a new firm. For that reason it may be highly desirable to limit periodic competition for contracts to firms which were previously qualified. The impact of repeated IFB competition

is also weakened if one contractor manages to win a number of consecutive contracts. The cost advantage obtained by the cumulative production experience may be insurmountable by the other firms so that competition becomes essentially ineffective.

2. Buy-Out for a Multi-Year Contract

At some point in the succession of reprocurements, an all-or-nothing buy-out competition for all of the remaining planned requirements may be feasible. With this approach, the total benefits of economies of scale and progress curve effects can be realized through the production of the total quantity by a single firm. Presumably the price competition would allow the government to appropriate a major share of the cost savings due to such economies.

The problem with using such a buy-out competition has been discussed in Appendix G. Under present circumstances multi-year contracts are often unfeasible--the government is incapable of making firm long-run commitments of funds; the instability of the economy plus imperfect escalation clauses make contractors unwilling to submit long-run price quotations; or the frequent changes in the system design, due to the submission of engineering change orders, results in so many negotiated changes that the sole-source environment is restored.

3. Split-Award Competition

Competition for relative shares of the annual procurement contracts by two or more firms is the obvious choice if multiple sources are desired for non-price reasons such as maintenance of the mobilization base. It is also used in leader-follower procurements and other forms of negotiated competition as a method to provide production experience to the second source before the final competitive all-or-nothing buy-out.

The usual approach to split-award competition is to request quotes from each of the contractors for, say, 20 to 80 percent of the planned procurement, in incremental steps of 5 to 10 percent. The government then selects the most beneficial combination.

In situations where reduction in system price is the primary motivation for competition and buy-out is not feasible, repeated split-award competitions between two experienced producers has much to offer. The costs, delays, and risks of introducing a second source are reduced to a one-time event (as opposed to repeated IFB competition). The potential loss in economies of scale and progress curve effects may be more than offset by continuous competitive pressure to shift the cost curve downward. Continuous production by two competitors also makes them natural candidates for competitively awarded R&D and production contracts on the next generation of the same system.

Use of split-award competition may be limited by the level of the procurement requirements. There is generally a minimum production rate below which it is not economical to produce. Also, there may be a tendency for the contractors to raise their prices for the smaller shares of the annual award in order to maintain their profits. This can be countered somewhat by the threat of receiving an even smaller share or no share at all if the price is too high, or by direct negotiation after the bids are submitted.

C. RECOMMENDED POLICY CHANGES

On the basis of our analysis of conversations with personnel involved with the procurement of weapon systems and the analysis of case studies of systems which were competed, the following policy changes are advanced. The intent of the recommendations is to encourage the use of competition and the

choice of an appropriate technique to implement it, when economically feasible, by reducing artificial impediments.

- As soon as possible: Make a firm commitment to the volume of future system requirements; require an analysis of expected net savings of the introduction of competition; and acquire the TDP, rights in data, and technical assistance when necessary for competition.

Introduction of competition may require substantial initial costs and extra lead time. The intent of these recommendations is to force the consideration of competition early enough to reduce costs when possible, accommodate long lead times, and subject as much of the actual production volume to competition as possible, in order to balance expected savings in system price against the front end costs. When there is unplanned expansion of the sole-source production quantities over time, opportunities for competitive reprocurement are lost. Instead of considering only the procurement of immediate concern, the planning analysis should balance the cost of initiating competition against expected savings on all reasonably foreseeable future procurement quantities. Total requirements of all the Services and anticipated foreign military sales should be included where possible in the procurement plan. Estimates of future requirements are subject to uncertainty for reasons discussed elsewhere, but even a tentative best estimate is more accurate and useful than an arbitrary assumption that there will be no requirements beyond those of the current contract. Finally, early acquisition of technical information and reproduction rights, before it is locked into a sole-source producer allows more effective use of the government's negotiating strength.

- Make appropriate funds and personnel available for the implementation of competition.

Competition can result in substantial savings, but not immediately. Two major constraints in the past have been

insufficient funds and insufficient personnel to cover the initial surge required to select and develop a second source.

- Provide multi-year appropriations for long-term contracts.

For some systems, the maximum reduction in price can only be obtained by an all-or-nothing buy-out competition in a multi-year procurement. A major deterrent to the use of multi-year contracts is the government's limited liability to the contractor in the event program termination is brought on by unavailability of funds. Such inability to make long term commitments increases the risk to the contractor and utlimately the cost to the government.

- Allow concurrent procurement of the same system or subcomponent from more than one source and at different prices in order to develop or maintain price competition.

It may be desirable for som systems to continue production by the original source while a second source gains production experience in order to avoid program stretchouts or undue risk of delivery interruptions. If multi-year contracts are untenable or the impact on technical performance is expected to be substantial, two or more firms may be sustained in order to compete for shares of the annual production contracts.

Under present regulations, the only justification for multiple sourcing is to maintain or improve the mobilization base, ASPR Exception 16. Continuation of the present policy can inhibit competiton, as it has in the past, for systems which cannot justify a second source for mobilization reasons. Use of Exception 16 as a subterfuge for introducing negotiated competition is, at minimum, misleading and distracting.

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APPENDIX A

MODEL FOR FORECASTING SAVINGS EXPECTED FROM PRICE COMPETITION

MODEL FOR FORECASTING SAVINGS EXPECTED FROM PRICE COMPETITION

The purpose of the following effort is to develop a model for forecasting expected savings from price competition. The model developed by the Army Procurement Research Office was unsatisfactory for three reasons: 1) it is an arbitrary model, rather than one having the explicit functional form determinable from learning theory; 2) it fails to use a sole-source learning rate, an important explanatory variable, as a factor in savings forecasting; and 3) it expresses savings as a fraction of the total buy, instead of forecasting the savings on future buys if competition is undertaken.

A simple savings model commensurate with learning theory can be developed using log (cumulative average price) vs. log (cumulative quantity) curves. The following notation is used:

- SSCAP = cumulative average price for the quantity produced sole source.
- ATCAP = cumulative average price of the total quantity procured, taking into account both sole-source and subsequent competitive buys.
- PTCAP = projected cumulative average price of the total quantity if sole-source procurement were continued.
- TQ = total quantity procured.
- SSQ = sole-source quantity procured.
- FQ = quantity procured competitively.
- SSS = sole-source learning curve slope.
- CS = competitive learning curve slope.
- FS = fractional savings on the total buy.
- FSFB = fractional savings on future buy.

Referring to Figure A-1, it can be seen that:

$$\log(ATCAP) - \log(SSCAP) = CS \log(TQ/SSQ) \qquad (1)$$

$$\log(PTCAP) - \log(SSCAP) = SSS \log(TQ/SSQ) \qquad (2)$$

Subtracting (2) from (1)

$$\log(ATCAP) - \log(PTCAP) = (CS-SSS)\log(TQ/SSQ) \qquad (3)$$

or

$$\frac{\log(ATCAP/PTCAP)}{\log(TQ/SSQ)} = CS-SSS. \qquad (4)$$

Note that the quantity ATCAP/PTCAP = 1-FS. Thus, the structural form (4) relates savings to total and sole-source quantities and pre- and post-competitive learning curve slopes.

For forecasting savings, we can use the structural form of (4), recognizing that CS, the learning curve slope, is not known in advance:

$$\frac{\log(ATCAP/PTCAP}{\log(TQ/SSQ)} = aSSS + b. \qquad (5)$$

The coeficcients a and b can be determined by regression analysis from the data tabulated in Table A-1 on 31 competitive procurements taken from prior ECOM, APRO, Tecolote and IDA reports. The criterion for selecting these 31 items was that there exists a sole-source price history of at least two points that, without data manipulation except for adjustment to constant dollars, permitted derivation of a sole-source learning curve.

Since, from (4) and (5)

$$CS-SSS = aSSS + b, \qquad (6)$$

regression leads to a linear relationship between predicted competitive slope CS* and the known sole-source slope:

$$CS^* = (a+1)SSS + b. \qquad (7)$$

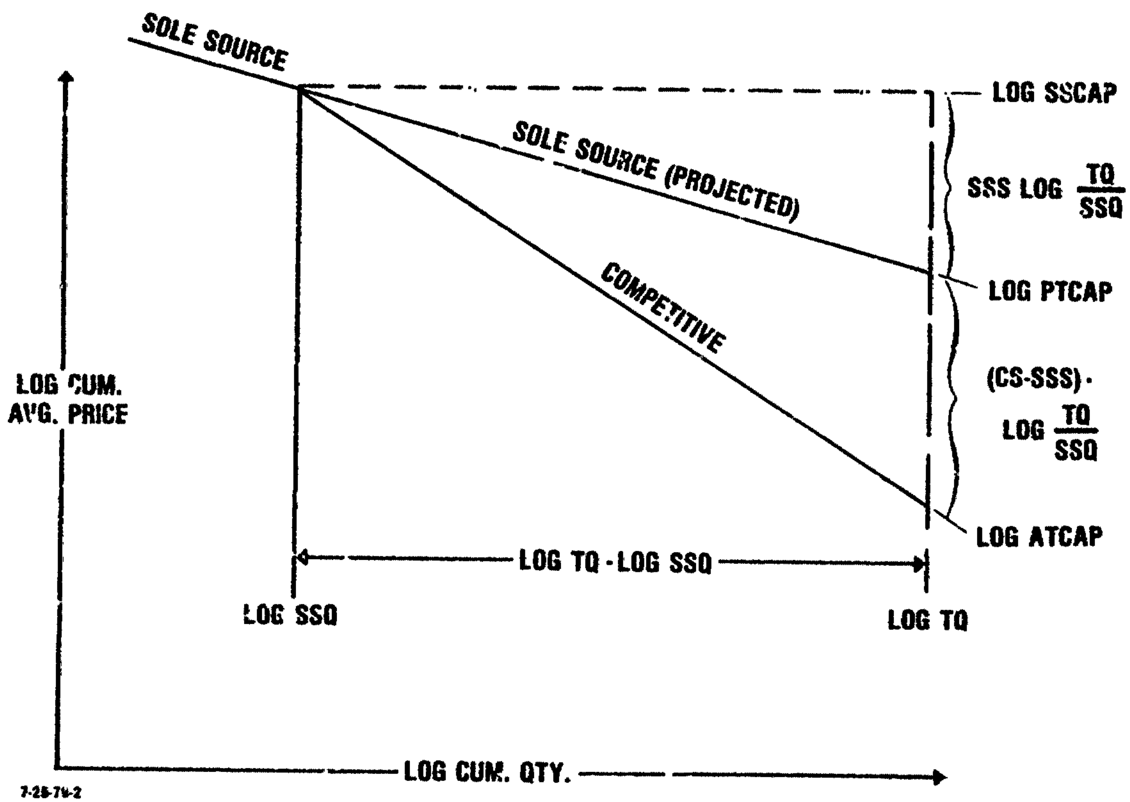

Figure A-1. BASIS FOR EXPLICIT SAVINGS MODEL

Table A-1. DATA SUMMARY

Item	Sole Source Learning Curve Slope SSS	Fractional Savings FS	Ratio, Total Qty. to Sole Source Qty. TQ/SSQ	log(1 - FS) / log(TQ/SSQ)	Computed Competitive L.C Slope CS	SSCAP	1-FSFB
ARC-54	- .15373	.149	7.69	- .07908	- .23281	6,715	.450
PRT-4	0	.355	5.21	- .26572	- .26572	355	.577
MK-980/PPJ-5	- .04863	.130	1.34	- .47743	- .52606	10,344	.440
AN/GRC-103	- .10907	.084	1.19	- .50668	- .61575	30,886	.413
AN/GRC-106	- .20994	.249	2.97	- .26327	- .47321	21,138	.567
AN/APH-123	+ .01551	.103	1.21	- .56151	- .54600	6,346	.388
PRC-77	- .14677	.168	7.41	- .09185	- .23862	1,315	.795
MK46	- .2925[illegible]	- .231	7.41	+ .10378	- .18874	50,746	1.230
TOW Missile	- .22538	.054	14.95	- .02053	- .24591	5,091	.911
TOW Launcher	- .06295	.392	10.92	- .20816	- .27111	44,465	.558
Bullpup	- .29352	.202	5.38	- .13415	- .42767	8,374	.683
AIM-9D/G gcg	- .12902	- .078	23.52	+ .02382	- .10520	10,568	1.046
AIM-9B gcg	- .28102	.0023	18.80	- .00078	- .28180	5,705	.984
Shillelagh	- .39034	- .033	4.91	+ .02039	- .36995	5,928	1.080
Std. missile	- .3125[illegible]	- .030	6.17	+ .01624	- .29[illegible]9	88,572	1.0415
Aero 60-640[2]	- .08793	.0851	1.24	- .41346	- .50139	7,51[illegible]	.506
AN/APX-72	- .33857	.0943	1.91	- .15306	- .49163	3,776	.729
TALOS G&C	- .11904	.114	1.46	- .31984	- .43888	177,662	.592
SPA-25	+ .43431	.136	1.23	- .70615	- .27184	8,358	.512
HAWK motor parts	- .19913	.188	1.78	- .36117	- .56030	1,816	.543
Rockeye bomb	- .24929	.0394	3.40	- .03285	- .28214	2,831	.884
USM-181	- .16440	.165	1.42	- .51425	- .67865	972	.440
FGC-20	- .06446	.032	1.16	- .21913	- .28359	2,019	.763
Aero 42-075C	+ .20633	.287	2.06	- .46807	- .44174	138	.452
Aero 42-2028	- .13770	.071	1.63	- .15074	- .28844	661	.801
ID-202	- .20006	.318	4.16	- .26P.8	- .46854	6,614	.532
ID-352	- .04369	.356	2.70	- .44305	- .48674	11,469	.420
ID-204	- .041[illegible]	.526	5.32	- .44654	- .48855	7,006	.379
ID-660	- .44165	.099	1.65	- .20818	- .64983	10,858	.617
MD-522	- .193C1	.245	1.89	- .44148	- .63449	4,165	.414
CV-1548	- .17756	.392	2.94	- .46140	- .63896	5,504	.360

Omitting just one aberrant item (the SPA-25) from the regression, the coefficient a+1 = 0, indicating that competitive slope is uncorrelated with sole-source slope. The average value of b = .414. Since a = -1, from (5) we find for the predicted cumulative average price after competition,

$$ATCAP^* = PTCAP\left(\frac{TQ}{SSQ}\right)^{-SSS - .414} . \tag{8}$$

The projected cumulative average price, if sole-source procurement were continued, is from (2),

$$PTCAP = SSCAP\left(\frac{TQ}{SSQ}\right)^{SSS} . \tag{9}$$

The total quantity is related to the sole-source quantity by

$$TQ = SSQ + FQ, \tag{10}$$

where FQ is the future quantity to be competitively procured.

The fractional savings on a competitive buy (relative to sole-source price projected from previous price history) can readily be seen to be

$$FSFB = 1 - \frac{(TQ)(ATCAP)-(SSQ)(SSCAP)}{(TQ)(PTCAP)-(SSQ)(SSCAP)} . \tag{11}$$

Substituting (8), (9), and (10) in (11), we find for predicted fractional savings FSFB* on a future competitive buy.,

$$FSFB^* = \frac{1-(1+FQ/SSQ)^{-SSS - .414}}{1-(1+FQ/SSQ)^{-SSS -1}} . \tag{12}$$

As one would intuitively expect, the greater the quantity competed, the greater the expected percent savings. Remarkably, however, savings are predicted even for small quantities (relative to the prior sole-source quantities) competitively procured, provided the sole-source learning-curve slope is no steeper than -.414 (learning rate of 75.0%). This result is confirmed by the many instances (see Table A-1) in which savings were

achieved even though the competitive buy quantity was smaller than the sole-source quantity (TQ/SSQ less than 2).

A. OBSERVATIONS DRAWN FROM THE DATA SAMPLE

Review of the data on 31 competed items of Table A-1 yields the following observations. It is important to recognize that the sample items may have been carefully selected as those worthy of competition:

1) The average savings on the competitive buys were 35.1 percent.
2) Price savings were achieved by competition on 87 percent of the 31 items.
3) Gross savings decreased with the steepness of the sole-source learning curve, with expected savings of zero when the curve was steeper than 75 percent.
4) The sole-source learning rate is not a good predictor of the competitive learning rate.
5) Savings are essentially independent of unit price, indicating that large, costly, complex items can be successfully competed as well as small, cheap, simple ones. However, no item costing more than $200,000 per unit was included in the sample. (There is some indication that the leader-follower arrangements used on complex items achieved smaller indicated savings than formal advertising, primarily because the explicit costs of developing a second source are taken into account, while the implicit costs of defaults and delays in formally advertised IFB procurements are not.)
6) Although one could reasonably expect different kinds of military items to yield different expected savings under competition, the sample was not large enough to permit segregation by kind.

B. CONCLUSIONS WITH REGARD TO USE OF THE MODEL IN FORECASTING

It must be remembered that the model is based on a sample of items that were probably selected as being worthy of competition. Further, the sample includes mostly items that were formally advertised. With these cautions in mind, the model

(equation 12) forecasts expected fractional savings on a future competitive buy. The model indicates:

1) Predicted gross savings, as a fraction of projected sole-source cost of a future buy, increase slowly with the ratio of future quantity to sole-source quantity. The implication is that competition should be started as early as possible to achieve maximum savings.

2) Gross savings are predicted, however, even for small competitive quantities. The implication is that it is never too late to compete unless, of course, the cost of undertaking competition exceeds the expected gross savings.

3) Predicted gross savings decrease as the sole-source learning curve becomes steeper. Expected gross savings reach zero for a learning rate of 75 percent (learning curve slope of -.414).

4) The break-even competitive buy-out quantity increases as cost of carrying out the competition increases and as the sole-source slope becomes steeper.

Because the sole-source learning curve slope is not a good predictor of the subsequent competitive slope, the savings forecasting model is only a moderately successful predictor of actual savings. Retrospectively applying the model to the 31 procurements of Table A-1 yields the actual *vs.* predicted savings shown in Figure A-2. Savings are predicted on 30 items and achieved on 27. The majority of the points, indicated by dots, are relatively uncomplicated items procured by formal advertising; many show actual savings greater than forecast. More complex items are shown by ▲'s; those procured by leader-follower techniques are indicated by ■'s, and show actual savings less than forecast, primarily because the excess costs of learning buys are charged against savings.

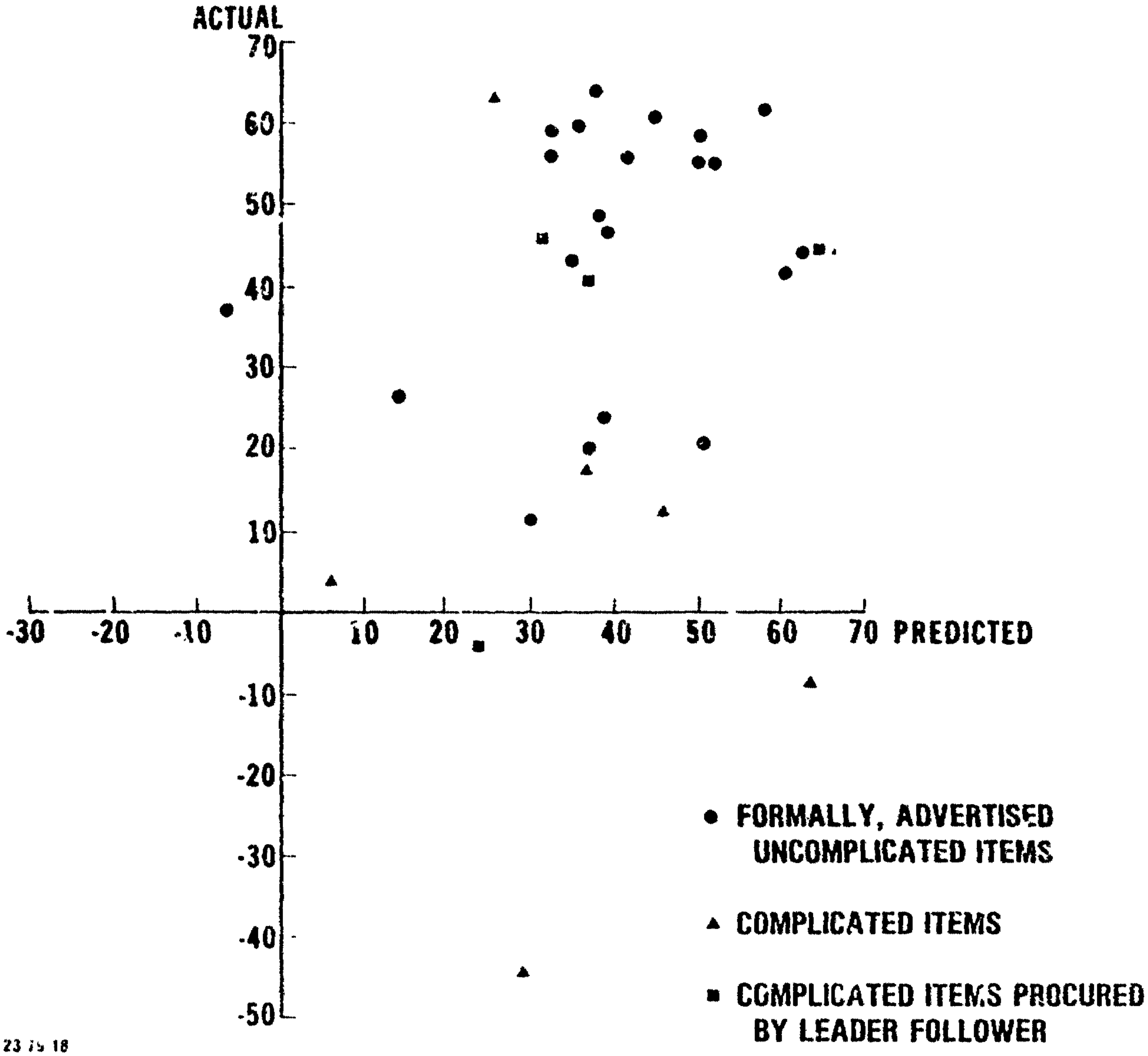

Figure A-2. GROSS PERCENTAGE SAVINGS ON UNIT PRICE FOR 31 SYSTEMS

APPENDIX B

SPARROW AIM-7F

SPARROW AIM-7F

A. DESCRIPTION

The SPARROW AIM-7F is a medium-range, air-to-air missile incorporating solid-state electronics which guides semi-actively to a target illuminated by radar signals from the launching aircraft.[1] The AIM-7F is used on the Air Force F-15 and the Navy F-14 and F-4J and is used by several allied countries as an expanded capability, all-weather, multi-purpose air-to-air weapon. The Naval Air Systems Command procures the AIM-7F on behalf of the Naval Sea Systems Command and the Air Force. The governments of Iran, Saudi Arabia and Israel have also procured several units through the Naval Air Systems Command. The AIM-7F version of the SPARROW missile is an assembly of the following components:

(1) Guidance and Control (G&C) section, which includes radomes, wings and fins, safety and arming cable, a MK-17 fuze triggering device and containers,

(2) Rocket motor, MK 58 MOD 3 and containers,

(3) Integrated warhead assembly.

The components are procured separately and assembled at naval weapons stations.

This study considers only competition for the production of the guidance and control section which represents from 80 to 90 percent of the total unit cost of the missile. Raytheon

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[1]All information in this paragraph was obtained from Procurement Plan No. P61-01-0-90, Naval Air Systems Command, Department of the Navy. Other data come from contracts, procurement plans, correspondence, memos and working papers available through the Naval Air Systems Command.

developed the AIM-7F G&C under contracts initiated in 1964. A contract for the delivery of 100 units was definitized in June 1973, and the procurement program for SPARROW III (AIM-7F) was approved by the Defense Systems Acquisition Review Council in October 1974.

B. ESTABLISHMENT OF SECOND SOURCE

The plan to introduce a second source was initiated early in 1971 before the technical data package had been proved by volume production of the AIM-7F by the developer, Raytheon, and at a time when the projected annual production quantities were around 3,000 units. Although requirements were later reduced substantially, the establishment of the second source was still justified by the requirement to establish multiple mobilization bases for all Department of Defense controlled equipment requiring more than six months to produce. Technical benefits were also expected to result from competition, but cost reduction was merely considered a possibility rather than a prime motivation. In fact, early projections showed an increase in procurement costs as a result of introducing a second source (Advanced Procurement Plan A61-01-0-30, page 20). Raytheon's difficulties with producing a workable missile contributed to a higher visibility of the program with respect to Congress, and may have reinforced the desire to initiate competition for technical improvements.

Five selected firms were provided with actual models of the AIM-7F G&C units to study for a minimum of six months. This approach was used in order to reduce the lead time required by waiting for the TDP to be validated by volume production by the original source before using it to select and establish a second source General Dynamics was selected as the second source on the basis of technical and cost proposal competition with Hughes Aircraft Company, General Electric, and Rockwell International On technical factors alone, General Dynamics would not have won, but the firm with the best technical proposal submitted a

considerably higher cost estimate. On the other hand, selection of the low cost firm would have required more management effort from the Navy and would have involved more risk.

Program delays in 1973 resulted in deletion of all but token funds for limited production of test articles. For that reason, the first contract awarded to General Dynamics in July 1973 was restructured into a two phase approach in order to delay the initiation of actual production and still maintain the availability of a second source. Cost incentive contracts for the two phases were used because a production validated TDP was still not available. Phase I was a cost plus fixed fee (CPFF) award for $1,158,961 for pre-production study and data generation. Phase II, a cost plus award fee (CPAF) of $21,189,961, was for the production of 15 first articles, an additional learning buy of 70 units, and special tooling and test equipment adequate for a production rate of 20 units per month.

The reduction in fiscal year appropriations and delays in passing the Defense System Acquisition Review (DSARC) Milestone III resulted in further schedule slippages for the second source plan. The slippages were not due to any deficiencies in the performance of the second source. Because of the delays in initiating Phase II and other problems, the 15 first articles were not delivered until 1976 and additional funds were required in a fiscal year 1976 contract in order to complete the production of the 70 units. The eventual estimated cost of these contracts was $23.3 million for the 1973 contract and $13.5 million for the 1976 contract for a total of $36.6 million. In addition to the production of the 15 units for first article testing and the additional 70 units, these costs included $5.6 million for special tooling and test equipment under the original contract and $3.1 million under the second contract to update that equipment. The modification was required by the substantial changes

in the configuration of the guidance and control units which occurred between 1973 and 1976. Allocation of the remaining $28.1 million between production of the 15 first articles and the other 70 units is arbitrary as the 1973 contract covered part of the costs of long lead items required for the learning buy of 70 units.

In 1976 General Dynamics was also awarded a fixed-price incentive contract for a quantity of 210 units and for an increase in special tooling and test equipment capacity to support production of 50 units per month. The first competition was held for the 1977 fiscal year requirements. Raytheon and General Dynamics each submitted bids for various specified shares of the total requirement. The government then selected the most beneficial combination of bids which resulted in a contract for 1,110 units with Raytheon and 210 units for General Dynamics. General Dynamics did not have sufficient production experience at the time to submit a truly competitive bid. However, the threat of losing the award of the larger share caused Raytheon to reduce its bid substantially below the price projected on the basis of its sole source experience.

Raytheon won the larger share again for fiscal year 1978, but General Dynamics won the larger share of the fiscal year 1979 contract. Present plans are to procure only 780 guidance and control units during fiscal year 1980, so no substantial buy-out is possible. The volume produced and the contract costs are listed in Table B-1.

C. EVALUATION OF NET SAVINGS

Estimation of net savings from competition requires a projection of what procurement costs would have been with a sole-source producer. Projections used by the Naval Air Systems Command were based on a constant dollar (unit prices adjusted for inflation) progress curve with a ninety percent slope, fit

Table B-1. SPARROW AIM-7F PRODUCTION CONTRACT VOLUME AND COSTS (THEN YEAR DOLLARS)

Year	Quantity	Unit Price	Total Cost
		Raytheon	
1972	100	232,780	23,278,000
1973	225	135,000	31,590,525
1975	600	94,721	56,832,770
1976	880	84,415	78,685,000
1977	1,110	74,000	82,140,000
1978	1,398	69,709	97,453,182
1979	900	66,993	60,293,817
		General Dynamics	
1973	15 First Articles		16,400,000
1974			
1975			
1976	70	200,000	13,500,000
	210	120,510	25,400,000
1977	210	106,090	22,278,000
1978	750	82,995	62,246,250
1979	1,310	61,083	80,018,730

to the average unit price for the 1976 procurement. The ninety percent slope reflects the actual slope between Raytheon's 1975 and 1976 contract unit prices, the last two sole-source procurements and Raytheon's production experience with the previous model AIM-7E, guidance and control unit. The actual projected sole-source contract production costs are shown in Table B-2 along with the actual combined costs of Raytheon and General Dynamics. All costs are expressed in 1979 prices. The projections assume that the 15 units produced by General Dynamics for a first article testing would not have been produced by a sole source, but that all other quantities produced by General Dynamics would have been. The cost of the 1973 Phase One

Table B-2. COMPARISON OF PRODUCTION COSTS
(1979 $000,000)

Year	Volume	Hypothetical Sole-Source Total Cost	Actual Two Sources Total Cost
1972	100	34.6	34.6
1973	225	47.0	71.4
1974			
1975	600	72.2	72.2
1976	1,160	122.1	140.0
1977	1,320	126.1	111.1
1978	2,148	190.2	159.7
1979	2,210	183.8	133.4
1980	780	62.8	47.1

preproduction contract is included but special tooling and test equipment costs are not included.

Table B-3 lists the special tooling and test equipment costs incurred to establish General Dynamics. However, only $3.1 million of those costs are attributable to the introduction of competition. That was the amount required to update the initial tooling and test equipment of General Dynamics for changes in design proposed by Raytheon. All of the other tooling and test equipment costs would have been incurred to expand the capacity of a sole-source producer if the second source had not been established.

The only government in-house costs explicitly attributed to the establishment and support of the second source are the contract costs with the Naval Weapons Center (NWC) at China Lake, California. The annual costs through 1976 are shown in Table B-3. The costs cover preparation of the Technical Data Package and technical support of the second source. One member

Table B-3. NONRECURRING COSTS

Year	In-House Costs	Tooling and Test Equipment
1972	$ 1.2	$(5.6)[a]
1973	4.2	
1974	2.4	
1975	3.7	
1976	4.6	3.1 (6.7)
1977		
1978		(5.8)
1979		
1980		
TOTAL	16.1	3.1

[a]Costs listed in parentheses would have been incurred by the first source if second source had not been established.

of the Navy civilian staff suggested that the listed contract costs may be higher than the actual costs incurred or required to support the second source. Any overstatement of those costs will tend to compensate for lack of information on the cost of extra testing and government admimistration required by the establishment of a second source.

The annual incremental production and development costs, government in-house costs, special tooling and test equipment costs, and savings, are listed in Table B-4. All figures are stated in 1979 prices. The annual incremental costs and savings are the difference between the projected sole source contract costs and the sum of the actual contract costs for Raytheon and General Dynamics. The contract for the projected 1980 requirements of 780 units had not been awarded at the time of this study. It is assumed that the same unit price will be paid for the 1980 buy as was paid in the 1979 contract.

Table B-4. SPARROW AIM-7F GUIDANCE AND CONTROL SECTION, COSTS AND BENEFITS OF PRICE COMPETITION, 1979 $M, ASSUMING A 90 PERCENT SLOPE FOR SOLE-SOURCE PROGRESS CURVE

Year	Incremental Production and Development Costs	In-House Costs	Tooling and Test Equipment	Direct Procurement Price Savings
1971		-2.0		
1972				
1973	-24.4	-6.2	(-8.1)	
1974		-3.4		
1975		-4.7		
1976	-17.9	-5.5	-3.7 (-8.0)	
1977				15.0
1978			(-5.8)	30.5
1979				50 4
1980				15.6
TOTAL	-42.3	-21.3	-3.7	111.5
ESTIMATED NET SAVINGS $43.7M				

Total extra costs to establish the second source were $67.8 million.[1] Subtracting that figure from the gross savings on later production contracts of $111.5 million yields an estimated net savings of $43.7 million. The break-even point does not occur until the third split-award contract competition in 1979. The rather long payback period results partly because of the schedule slippages which delayed the delivery of the 15 first articles and the learning buy of 70 articles contracted with General Dynamics. Inevitably, it will take a substantial period of time to recover the start-up costs of developing a second source for the production of complicated systems and components.

[1]Of the tooling and test equipment costs, only the $3.7 million incurred for modification is included as a cost of establishing the second source.

The savings should be expressed in terms of the rate of return on investment in order to reflect the pattern of the annual cash flow and the opportunity cost of funds. The calculation is illustrated as follows:

$$NPDV = -2.0 - \frac{30.6}{(1+r)^2} - \frac{3.4}{(1+r)^3} - \frac{4.7}{(1+r)^4} - \frac{27.1}{(1+r)^5} + \frac{15}{(1+r)^6} + \frac{30.5}{(1+r)^7}$$

$$+ \frac{50.4}{(1+r)^8} \quad \frac{15.6}{(1+r)^9}$$

$$r = 0.12 \qquad NPDV = 0 \; .$$

The equation for the net present discounted value (NPDV) with annual net cash flows in the numerator of each term is equated to zero. By solving for r, the rate of return of 0.12 or twelve percent is derived.

D. SUMMARY OF BENEFITS

Twelve percent is a rather modest rate of return. Given the discount rate of 10 percent recommended for use by the Office of Management and Budget,[1] the introduction of competition for the SPARROW AIM-7F Guidance and Control system is roughly a break-even investment in financial terms. However, it is encouraging that a break-even return could be obtained for a relatively complicated item which was not projected to break even, which experienced cost overruns and delays in developing the second source, which had an unexpected reduction in procurement requirements, and which experienced only split-award competitions.

General Dynamics experienced some technical problems with its 1977 production, but by 1979 General Dynamics was producing

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[1]OMB Circular No. A-94, March 1972, Office of Management and Budget.

smoothly and Raytheon was experiencing difficulties with delivery. The second source, General Dynamics, developed the use of reinforced steel wings to replace the use of titanium. A nonrecurring expenditure of $500,000 by the government to implement this change results in a savings of $1,500 per set of four wings.

There are other benefits of introducing a second source other than the effect on unit price of the AIM-7F. Because of experience with the AIM-7F, General Dynamics was able to provide Raytheon substantial competition for the development of the Improved Seeker (Monopulse) which will replace the current guidance and control system. Raytheon's design was chosen, but General Dynamics will be the second source for the production of the new guidance and control system. Presumably, General Dynamics will be able to begin production and effectively complete the system sooner, and with less difficulty, because of previous experience with production of the AIM-7F.

APPENDIX C

IMPROVED HAWK

IMPROVED HAWK

In 1974, the Army Mi--ile Command performed an analysis of the feasibility of competitive reprocurement of production quantities of the Improved Hawk missile, which had previously been developed and produced by a sole source.

The plan was to competitively reprocure the guidance section, radome, actuator and control section, and fuzing antenna, together with assembly of the complete round. Other hardware components of the missile were, and would continue to be, broken out and procured from other contractors and furnished as government-furnished equipment to the successful offeror.

At the time MICOM's analysis was made, requirements existed for 3,187 missiles whose production was not yet under contract. The plan for development of a second source required approximately 54 months lead time, which implied a program deferment of three years, until deliveries could start under a competitive buy-out. The plan involved the following steps:

1) To meet immediate requirements, procurement of 520 missiles from the original sole source.
2) Issuance of a request for proposals to qualified sources, excluding the original producer, and award to the successful offeror of a quantity of 30 initial production missiles for test.
3) Government test of the second-source-produced initial production quantity.

4) Second- and third-year awards to the second source of contracts for 120 and 110 production missiles, respectively, with production rates of approximately 10 per month.

5) Concurrent third-year sustaining award to the original source of 130 production missiles, with production rates of 10 per month.

6) Competitive buy-out of 2,307 missiles.

Quoting from the procurement plan,

> " Establishment of a second source will require facilitization of the second-source producer, initial production testing, separate lot acceptance testing and additional contractor and Government engineering support. The total cost of these additional requirements is $35.8 million as shown below ($millions).

Special Tooling	$ 4.700
Factory Test Equipment	9.400
Initial Production Facilities	1.900
Industrial Plant Equipment	4.600
Vendor Qualification	2.223
Complete Round Assembly Facility	.756
Initial Production Test	2.487
Lot Acceptance Costs	2.600
Theater Readiness Monitoring Equipment	1.455
Contractor and Government PA Engineering	2.793
Contract and Government Engineering	2.901
	$35.821

The total estimated incremental costs of the planned program included the starting costs previously detailed, the increment in sole-source prices consequent on reduction of planned quantities, the cost of second-source missiles for test and the increment of price of the small second-source educational buy over the estimated price of an equivalent sole-source quantity. We identify these cost components (relative to average cost under the sole-source plan) as follows:

Starting costs (in $ million)	$ 35.8
Incremental cost of reduced sole-source quantities (650)	15.2
Cost of second-source missiles for test (30)	12.2
Incremental cost of educational buy (230)	8.4
Total incremental cost (in $ million)	$ 71.6

The unit price reduction projected for the buy-out competition was 28 percent of the projected unit price ($91,211) for the final buy under the previous all-sole-source procurement plan. The apparent saving due to competition aggregated $59.5 million. However, because the final-buy price was greater by 12.5 percent than the average price under the sole-source plan, the savings relative to the average sole-source price was only $36.1 million. The difference, $23.4 million, is attributable to the projected impact of inflation over the three year period of program deferment needed to develop the second source to the point where it could effectively compete.

In summary, the net benefit (loss) ascribable to competition under the proposed program can be stated as follows:

Price reduction due to competition	$ 59.5 million
Less: Total incremental cost of preparing for competition	(71.6)
Less: Inflation loss due to program deferment	(23.4)
Benefit (loss) due to competition	($ 35.5 million)

Because competition would lead to an increase in total program cost of $35.6 million in current dollars, the plan for undertaking competitive production procurement was abandoned in favor of continued sole-source procurement.

A. CONFIRMATION OF THE SAVINGS ESTIMATE

An estimate by the Hawk Program Manager of the learning rate of the sole-source producer was 88.5 percent on a unit price, rather than a cumulative average price basis, with an estimate of first unit cost of $189.040. Whether the slope was adjusted for inflation is not known.

The guidance and control section is the most complex and expensive part of the missile, and represents the majority of the missile cost. Its cost history is shown in Table C-1.

Our analysis of the data in Table C-1 indicates that the cumulative average price (CAP) is related to cumulative quantity (CQ) as follows:

$$CAP = 539,365\ (CQ)^{-.25591}$$

The exponent -.25591 corresponds to a learning rate of 83.7 percent.[1]

Using the steeper learning curve slope of 83.7 percent derived for the guidance and control system as representative of the missile in its entirety, and noting that the planned competitive buy of 2,307 represented approximately 51 percent of the prior sole-source quantity of missiles (excluding certain foreign sales), one can estimate expected gross savings through competition on the future buy using the method of Appendix A. The estimated savings is 24 percent, which is in fair agreement with the estimate used by the project manager.

[1]Analysis on the basis of unit price, rather than cumulative average price, yields an exponent of -.268, corresponding to a learning rate of 83.1 percent.

Table C-1. IMPROVED HAWK G & C SECTION COST-QUANTITY HISTORY

Year	Quantity	Contract Type	Unit Price Thousands	Total Millions CY $	Total Millions 1972 $	Cum. Qty.	Cumulative Aver. Price 1972 $
1968	41 proto.	CPIF	$164	$ 6.7	$ 7.7	41	$ 188,744
1969	100	CPIF	144	14.4	15.8	141	167,121
1970	330	FPI	93	30.7	33.2	471	120,620
1971	566	FPI	65	36.8	36.8	1,037	90,272
1972	1,841	FPI	55	101.5	101.5	2,878	67,794
1973	1,150	FPI	51	59.2	57.8	4,028	62,798

B. CONCLUSIONS

There are apparently three principal reasons for the negative savings projected as an outcome of Improved Hawk Competition. The first of these is the substantial program postponement implied in reserving a quantity for buy-out competition until a viable second-source competitor could be developed. This postponement could cost an estimated $23.4 million.

The second reason is the efficient performance of the original sole source, as evidenced by the 84 percent learning rate on the guidance and control system, a major component that accounts for a majority of the missile cost. Confirmation of the original producer's efficiency is found in the perceptions of several responsible and competent potential competitors, who declined to give assurances that they would compete, citing the original producer's unassailable competitive position. Had the learning curve been less steep, say 93 percent, we would have projected the savings to be 39 percent instead of 24 percent, increasing the expected dollar savings on a quantity of 2,307 by $32 million.

Third, the buy-out quantity was not sufficiently large, given the steep learning curve of the original producer. By our estimates, the break-even point after program postponement was a buy-out of 4,350 missiles.

Competition could well have provided large dollar savings in the production of Improved Hawk had the decision to compete been made three years earlier, in 1971. No program postponement would have been necessary, thus saving $23.4 million foregone to inflation Approximately 4,000 missiles could have been competed in a buy-out competition, with a projected savings of $80.3 million, which would have substantially exceeded the estimated incremental costs of competition of $71.7 million.

This is not a criticism of the decision, at the time it was made, to continue sole-source procurement; rather, it is intended to illustrate the importance of early planning for competitive production procurement.

APPENDIX D

FFG-7 GUIDED MISSILE FRIGATE

FFG-7 GUIDED MISSILE FRIGATE

The Navy's FFG-7 program is an example of application of the leader-follower technique to a highly complex item--a class of ships whose all-up unit cost is in excess of $150 million. Since the argument is often advanced that competition is unfeasible because of the difficulties of technology transfer on a complex item, the FFG-7 serves as a counterexample.

The nominal objective of establishing dual sources for the FFG-7 was maintenance of the national mobilization base. There is significant excess shipbuilding capabity in the United States, and spreading the work was desirable in the interest of keeping shipbuilders viable. Exception 16 of the Defense Acquisition Regulations was used to justify the negotiated competition. However, from the beginning it had been envisioned that FFG-7 class ships would replace obsolete World War II destroyers. Large quantities were expected to be procured, and holding price down through the threat of competition was an important objective. The current program plans for 59 ships, of which 29 are currently under contract, 26 for the U.S. Navy and 3 for the Royal Australian Navy.

Two other factors played a part in dual sourcing. Originally an aggregate production rate of eleven ships per year was desired by the Navy (though Congressional authorization has never permitted more than eight). A nominal production rate of three to four ships per year could be accommodated by most qualified shipyards; clearly, then, it was likely that three yards would be needed to meet delivery requirements while avoiding the disruptive effects on the shipbuilder and the community that a concentration of the work in a single yard would bring.

Second, it was desirable to geographically diversify an important national defense activity.

The Navy, with the assistance of the Naval Ship Engineering Center, developed ship concepts and accomplished the preliminary design. A competition was then held among shipbuilders for ship system design (sometimes called "contract design"). The ship system design, developed from the preliminary design with the assistance of the winning contractors, was to be the basis for later lead-ship detailed design and construction. The dollar amounts involved in these support contracts were small compared to the significance of winning the competition: one of the two planned winners was to be designated "lead" shipyard, with the potential for ultimately performing lead-ship detail design and construction; both winners were to be designated potential "follow" yards, with the potential for building substantial numbers of ships to the detail design. Both winners were to contribute to the ship system design so as to assure produceability in the facilities of either.

The winners were Bath Iron Works, designated as the lead yard, and Todd Pacific Shipyards Corporation, Seattle Division, designated as a follow yard. Cost-plus-fixed-fee contracts were made with Bath and Todd for ship system design support.

Subsequently, upon completion of the ship system design, Bath was awarded a cost-plus-incentive-fee contract for preparation of detailed working drawings and construction of the lead ship. The firm of Gibbs and Cox, naval architects, served as design subcontractor to Bath on both the ship system design and the subsequent detailed design.

A gap of two years was planned between the award of the lead-ship construction contract and award of follow-ship construction contracts to permit adequate time for testing of major ship components, including the propulsion system, before follow-ship award.

Shipyards differ substantially in their processes, procedures and facilities. For example, the three shipyards ultimately involved in building guided missile frigates were Bath, which constructs pre-outfitted ship modules that are subsequently assembled to become a ship; Todd Los Angeles, whose construction technique is described as "semimodular", with a moderate amount of pre-outfitting; and Todd Seattle, which constructs ships piece by piece on ways in the classical fashion with subsequent outfitting. To accommodate these differences, follow ships of the FFG-7 class were procured to a specification essentially identical to that of the lead ship, and under provisions that motivated but did not mandate contractors to use lead-ship working drawings. These provisions essentially were that the government bear the responsibility for ship performance where lead-ship drawings were used, but required the contractor to prove compliance with ship performance specifications if deviations were made from the drawings.

This approach contributed to a high degree of standardization among ships of the class. Additional standardization was obtained by three methods: combat system and communication equipment for the ships was procured by the Navy and furnished to the shipbuilders as GFE; gas turbines, diesel generator sets and main reduction gears were centrally procured by Bath as agent for the Navy and furnished as GFE to shipbuilders; 42 major mechanical and electrical equipments were "directed procurements" by the follow yards--that is, specific equipments were to be obtained from suppliers specified by the government. Finally, working drawings and test procedures were "validated" by the government for use by the follow yards, and drawings were maintained and changes to them controlled by Gibbs and Cox, acting as the Navy's Contract Design Agent.

The history of competition on the FFG-7 class program is as follows:

1) Bath and Todd were competitively selected as ship-system design support contractors based on a competition held in 1971. Bath was subsequently awarded a contract (1973) for development of working drawings and lead-ship construction.

2) A competition was held in 1975 for the first fleet of follow ships. Only Bath and Todd bid, with other bidders begging off because of their lack of detailed familiarity with the program and for other reasons. Fixed-price incentive fee contracts containing escalation provisions were awarded for the initial years production, with options for the second year. These options were subsequently exercised.

3) In 1977, a competition was held for the second fleet of follow ships. Again, only Bath and Todd bid. FPIF (with escalation) awards were again made for the next year's production, with options for the following year that were subsequently exercised.

The two-year procurement cycle--one year plus options for one year--was designed to meet two requirements: the annual nature of congressional appropriations, and the uncertainty of future appropriations; and the desire of the Navy to assume a greater burden of risk of price increases in an unstable economy rather than shifting that burden to the contractors, as would be the case with priced options extending beyond the second year.

The price history of the FFG-7 program[1] is given in Figure D-1, together with the computed constants for cumulative average price-cumulative quantity learning curves.

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[1] Excludes the lead ship and one follow ship (FY-78) for the Royal Australian Navy.

Table D-1. FFG-7 CLASS FOLLOW-SHIP PRICE HISTORY[a]

YEAR	Todd L.A.			Todd Seattle			Bath Iron Works		
	Qty.	Cum. Qty.	Cum. Ave. Price ($1000)	Qty.	Cum. Qty.	Cum. Ave. Price ($1000)	Qty.	Cum. Qty.	Cum. Ave. Price ($1000)
FY75	1	1	56812	1	1	56812	1	1	52041
FY76	2	3	48858	2[b]	3	49680	4	5	44759
FY77	3	6	47575	2	5	28546	3	8	45354
FY78	3	9	46268	2	7	27075	3	11	45000
Initial unit price			55911			56360			51461
Learning curve slope			-.09230			-.09614			-.06385
Learning rate			93.8%			93.6%			95.7%

[a]Contract prices adjusted to January 1975 base month. Excludes contract change and GFE costs.

[b]Royal Australian Navy Ships.

The lowest-cost producer, Bath, has a less steep learning curve than either of the Todd yards. But by reason of the steeper learning curves, Todd FY 1978 per-ship unit prices (as differentiated from cumulative average prices) were lower than Bath's in spite of the handicap of a $2 per hour positive wage differential on the West Coast and a labor requirement of approximately 2 million hours per ship.

REFERENCES

Newcomb, John W. and Anthony R. Di Trapani. "The Patrol Frigate Program--A New Approach to Ship Design and Acquisition." *Naval Engineers Journal,* August 1973.

Beecher, John D., Captain, and Anthony R. Di Trapani. "The FFG-7 Guided Missile Frigate Program--Model for the Future?" *Naval Engineers Journal,* June 1978.

APPENDIX E

ARMY PROCUREMENT OF LIGHT OBSERVATION HELICOPTERS (LOH), OH-6A and OH-58A 1959 TO 1973

ARMY PROCUREMENT OF LIGHT OBSERVATION HELICOPTERS (LOH), OH-6A and OH-58A 1959 TO 1973

The procurement of the OH-6A is an example of a major weapons system procured under the two-step competition process. The follow-on procurement of the OH-58A is still another example of the use of competition in helicopter procurements. A brief review of the procurement of the OH-6A and OH-58A provides an insight into the impact of competition on prices of major weapons systems.

A. OH-6A

In October, 1979, the Army announced its aircraft development plan for the period 1960 to 1970. This plan stated a requirement for the Light Observation Helicopter (LOH) as a replacement for the OH-13 and OH-23 helicopters and the O-1 airplane. In December, the Army's requirements were presented to aircraft manufacturers. Industry responded with 45 different studies for the LOH role. After analyzing the industry proposals, the Army stated that its observation mission could best be performed by a pure helicopter, selected by means of a competitive R&D phase during which a single model would be selected for the production phase.

The RFP was issued to industry in October 1960. Industry was informed that:[1]

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[1] Report of the Subcommittee for Special Investigations of the Committee on Armed Services, United States Congress, House of Representatives, Ninetieth Congress, First Session, Review of Army Procurement of Light Observation Helicopters, July 18, 1967, page 8.

As a result of the competition, it is planned to award contracts to those two responsible bidders whose proposals are judged to be the most advantageous to the Government, design, price and all other relevant factors considered. It is expected that the contract to be negotiated with each of the two successful bidders will provide for the design, mockup, tests, and construction of a quantity of sever prototype flight articles, using prototype tooling. Following contractors' demonstrations, an intensive Army-Navy flight test and evaluation is planned. One of the two models may be selected to be continued in follow-on production.

Twelve manufacturers responded with seventeen design proposals. Of these, Bell Helicopter Company and Hiller Aircraft Corporation were initially selected as the two winners; however, upon reconsideration, the Army included Hughes Tool Company, Aircraft Division as the third contender in the competitive R&D phase. Hughes was initially eliminated from consideration because its design was considered beyond the engineering and manufacturing capabilities of the period; at the same time, the Hughes' design was also considered the best one.[1] On 13 November 1961, the Army awarded firm fixed-price R&D contracts to Bell ($5.78M), Hiller ($6.54M), and Hughes ($6.35M) for the development of five helicopters by each firm with delivery of prototypes within the period December 1963 to June 1964.[2]

Upon acceptance, the helicopters were subjected to flight test and field evaluation. In August 1964, the contractors were requested to submit cost information on their designs for purposes of program planning. Costs were to be based on production quantities of 714 (three-year multi-year program, 88, 168, and 458), 3,000 and 4,000 helicopters. (Neither the government's nor the contractor's estimates are available,

[1] Hearings before the Subcommittee for Special Investigations..., *Idem.*, p. 7.

[2] Report of the Subcommittee for Special Investigations..., *Idem.*, p. 8.

however, the Research Analysis Corporation conducted a study of the cost of an LOH and determined its cost to be in the range of $59,000 to $69,000 depending on quantities, 431 or 1,722 LOHs.[1]) The Government's program cost estimates for the Bell design were greater than Hiller's and Hughes' costs. At the 741 quantity, Hiller's costs were below Hughes, but at the larger quantities, Hughes' costs were below Hiller. The Army Cost and Evaluation Report included the following comment:[2]

> It is considered significant to note that the program cost developed may vary appreciably when prices are requested in a competitive atmosphere; validation is accomplished through audit of source data; and actual face-to-face negotiations are conducted. Historically, it has been shown the prices obtained through competitive means are approximately 25 percent lower than those obtained on a sole-source basis. It should be noted that quantity procured will have a direct bearing on prices ultimately negotiated. It is not considered outside the realm of reason that one or more of the contractors would be willing to "bargain" within reasonable limits, in view of the long-range potential that this program offers with its attendant probabilities of future profit.

In October 1964, the LOH Design Selection Board determined that the Bell design was the least desirable and that the Hiller and Hughes designs were about equal. None of the designs completely met the Army's requirements. Bell was eliminated from the competition. Hiller and Hughes continued into Step I of the competition. (Note: Bell made the necessary modifications to its design, produced a commercial version, and later in 1968, won the LOH follow-on competitive production procurement against Hughes.)

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[1] RAC Air Assault Concept Studies—1963, Appendix D, *Cost and Effectiveness Analysis of Light Observation Aircraft*, Research Analysis Corporation, February 1964, p. D-1-53.

[2] HASC Report, 18 July 1967, p. 14.

The procurement plan identified the method of procurement as a (three-year) multi-year, two-step formal advertising procedure limited to Hiller and Hughes. Step I was a technical qualification step with each firm submitting for government approval engineering fixes for discrepancies found during test and evaluation. Step II was purely price competition, since both designs were technically qualified in Step I. The contract was a firm-fixed-price type with a 50 percent option increased quantity above the quantity of 714 helicopters. The 714 helicopters represented FY 65, 66 and 67 requirements in respective quantities of 88, 168 and 458. In addition, as part of the proposed contract, a requirement for a Technical Data Package was included to be used for future competitive procurements of the complete helicopter. (This requirement for a TDP was later deleted because the overall cost estimate was approximately $26M--information based on recall of events occurring in Step I, 1965.) The Army's authorized objective was 3,313 helicopters--proposed contract 714 + 357 (50 percent increased option) = 1,071 plus follow-on procurement of 2,242.

On 1 May 1965, the second step (IFB) was issued to Hiller and Hughes, requesting unit airframe price bids (engine not included since it was a GFE item) and total contract prices for FY 65, 66 and 67 procurement of 714 helicopters on a three-year multi-year contract. Bids were required by 21 May with proposed contract award by 26 May 1965. During the period 1 May to 26 May, the government evaluated the LOH program costs in comparison with Hiller and Hughes bids. A breakdown of the government's estimates are shown in Table E-1.[1]

[1] Independent Government Cost Estimate for LOH Airframe, Directorate of Procurement and Production, US Army Aviation Materiel Command, St. Louis, Missouri 63166, 15 April 1966.

Table E-1. GOVERNMENT ESTIMATE

714 Helicopters (Unit Cost)

ITEM	DESIGN	
	HILLER (OH-5A)	HUGHES (OH-6A)
Material, Supplies, Equipment	$ 6,285	$ 4,556
Labor	9,144	7,871
Indirect Costs	15,539	13,213
Profit and Fee	3,097	2,564
Total	$34,065	$28,204

714 Helicopters (In Production)

ITEM	DESIGN	
	HILLER	HUGHES
Material, Supplies, Equipment	$ 4,487,490	$ 3,252,984
Labor	6,528,816	5,619,894
Indirect Costs	11,094,846	9,434,082
Profit and Fee	2,211,258	1,830,696
Total	$24,322,410	$20,137,656

On 21 May 1965, Hiller and Hughes' bids were publicly opened with unit airframe and total contract prices shown below in Table E-2.[1]

Table E-2. EVALUATION OF BIDS RECEIVED UNDER IFB

ITEM	(Unit)	HILLER	(Unit)	HUGHES
Airframe	$29,415	$21,002,310	$19,860	$14,180,040
Publications		408,297		210,234
Avionics Literature		41,796		5,019
Engineering Data		72,675		10,300
Selected Repair Parts		225,884		289,674
Special Tools		103,161		271,696
GFAE		365,568		--
Rental Gov't. Property		(81,982)[a]		1,699
TOTAL EVALUATED BID		$22,250,134		$14,968,663

[a]Included in airframe price (All numbers rounded.)

As indicated above, Hughes was the winner and low bidder at $19,860 per airframe and $14.2M for total contract. While the "cost" estimate in support of Hiller's bid price of $29,415 is not available, the Hughes cost estimate in support of the $19,860 price is shown below in Table E-3.[2]

[1]Independent Government Cost Estimate for LOH Airframe, *loc. cit.*

[2]Hearings before the Subcommittee for Special Investigations,..., *op. cit.*, p. 318.

Table E-3. HUGHES COST ESTIMATE (AIRFRAME)

Helicopter Quantities	714	1,700
Labor (using 80% curve)	($11,230)	($ 8,494)
Labor + Allocatables	14,936	11,042
Materials (using 92% curve)	17,046	15,358
TOTAL (does not include G&A & FEE)	$31,892	$26,400

NOTE:[1] Hughes interdepartmental correspondence reveals rationale the company used to obtain the unit airframe cost of $19,860. Hughes assumed that total production from Army, FMS, and commercial would amount to 1,700 units; thus, the basic airframe unit price would be $26,500. To this amount G&A would increase the total to $30,200. At the time Hughes estimated that profits (licensing, fees, and other business, etc.) would be approximately $10M. Hughes estimated that it could afford to lose this amount to win the contract. The bid price was set at $20,000 per helicopter. To keep from submitting a round figure in a sealed bid, the price was reduced to $19,860.

Actual costs to Hughes to produce 1,071 OH-6A helicopters are shown in Table E-4 (costs not audited by the government).[2]

Table E-4. AIRFRAME (1,071 OH-6A HELICOPTER)

Total Direct Material Costs	$11,560,800
Total Manufacturing Labor Costs	46,133,100
Total Other Direct Costs	563,600
Outside Production & Services (not included above)	22,539,900
G&A & Profit	--
TOTAL	$80,797,400

[1] Hearings before the Subcommittee for Special Investigations,...,*Idem*, p. 316.

[2] DD Form 1558-1, Cost Information Report Functional Cost-Hour Report, OH-6A, Hughes Tool Company, Aircraft Division, Culver City, CA, as of 28 March 1969, dtd. June 13, 1969.

The 1,071 helicopters cost $80.7M to produce, or $75,441 per airframe. On the original contract the comparable price for 714 helicopters was $20,964. Allowances for escalation (15%+) and engineering changes would reduce the difference in costs, but would never eliminate it.

B. URGENT ARMY REQUIREMENT FOR 121 OH-6A HELICOPTERS

In September 1965, the Army began the development of a budget request for procurement of 121 OH-6As above contract quantities. In response to an RFP of 20 January 1966, Hughes' initial target price per airframe was $55,927, an increase of $36,067 from the bid price of $19,860, dated 26 May 1965. A comparison of Hughes' proposal with the government's estimate is shown in Table E-5.

Table E-5. FIRST OFFER (AIRFRAME COSTS) 20 JANUARY 1966[1]

	HUGHES	GOVERNMENT
Total Direct Material Costs	$19,529	$17,466
Total Manufacturing Labor Costs	17,112	8,429
Total Other Direct Costs	8,183	4,429
G&A	(11.4%) 5,110	(9.4%) 2,850
Total Costs	49,935	33,177
Profit	5,992	3,317
Ceiling Price	$55,927	$36,495
LAST OFFER (AIRFRAME COSTS) 20 APRIL 1966		
Total Direct Material Costs	$17,998	$17,998
Total Manufacturing Labor Costs	14,071	12,234
Total Other Direct Costs	6,887	6,556
G&A	4,090	3,862
Profit	6,457	4,471
Ceiling Price	$49,505	$45,124

[1] ODCSLOG Information Sheet #41, Department of the Army, Subject: Negotiations held 28-29 March 1966, dtd. 11 September 1966; (continued on next page)

The two areas of disagreement were labor and profit. The final offer resulted in the following:

Ceiling Price	$52,088	$46,751
Target Price	47,353	44,718
Target Cost	43,048	40,653

No agreement was reached. Negotiations were terminated 11 May 1966. As noted above, Hughes' low offer was $47,353, and the government's was $44,718 per airframe.

C. FOLLOW-ON PROCUREMENT OF 2,200 LOHs

Early in FY68, the Army announced to industry its intention to procure 2,269 additional LOHs by formal advertising procedures. The method of procurement would be through the use of the two-step competitive process for multiyear quantities: FY68--600, FY69--600, FY70--600, and FY71--400 each. An option for 50 percent increased quantities was included in the total. The procurement was open to all manufacturers. Of the 39 firms solicited, only three (Bell, Hiller and Hughes) submitted notices of intent to participate. Hiller withdrew on 27 January 1968. Step II of the IFB was issued to Bell and Hughes. Bids were received (Table E-6) from Bell and Hughes:

Table E-6. BID EVALUATION - LOH PROCUREMENT

	HUGHES (OH-6A)		BELL[a] (OH-58A)	
Airframe--2,200	($59,700 each)	$131,340,000	($53,450 each)	$117,590,000
Total Program Costs		137,519,000		123,087,000

Source: Memorandum for Secretary of the Army, Subject: LOH Procurement, from ASA (I&L), dtd. 4 March 1968.

[a]Bell, the low bidder, was awarded the contract on 8 March 1968 for the production of 2,200 OH-58A helicopters.

(cont'd) and, ODCSLOG Information Sheets #50 and #55, Department of the Army, Subject: Summary of Negotiations with Hughes Tool Company for 121 Additional OH-6A Helicopters, dtd. 12 September 1966.

The government's estimates for production of 2,200 helicopters are shown in Table E-7.

Table E-7. GOVERNMENT ESTIMATE

AIRFRAME COST		
ITEM	DESIGN	
	HUGHES	BELL
Material, Supplies, Equipment	$ 10,658	$ 23,863
Labor	10,588	5,468
Indirect Costs	21,115	13,263
Profit	4,236	4,259
TOTAL	$ 46,597	$ 46,853
2200 HELICOPTERS		
Material, Supplies, Equipment	$ 23,447,600	$ 52,498,600
Labor	23,293,500	12,029,600
Indirect Costs	46,453,000	29,178,600
Profit	9,319,200	9,369,800
TOTAL AIRFRAME COSTS	$102,513,400	$103,076,600
Technical Data	1,700,000	1,900,000
Repair Parts	7,600,000	7,600,000
Special Tools	320,000	320,000
Training Aids/Devices	1,200,000	1,200,000
TOTAL PROGRAM	$113,333,400	$114,096,600

Source: AMC Form 1011-R, Independent Government Cost Estimate Prior to Contract Negotiation, LOH. US Army Aviation Material Command, St. Louis, Missouri, dtd. 15 February 1968, and 26 February 1968.

Bell's contract ceiling price ($12[illegible],087M) was 9.7 percent above the government's program cost estimate of $114,096,600. The contract with Bell was a fixed-price contract with provisions for escalation. A breakout of Bell's contract costs as

of 30 June 1968 (contract award date was 8 March 1966) and 30 June 1973, contract completion, is shown to indicate the differences in cost elements. However, the difference in contract ceilings ($25.5M) is composed of engineering changes, escalation, and cost growth.

Table E-8. A COMPARISON OF BELL COSTS INCURRED IN THE PRODUCTION OF 2200 OH-58A HELICOPTERS

	Estimate 30 June 1968[a]	Actual Costs for 2,200 OH-58As 30 June 1973[b]
Total Direct Material Costs	$ 36,625,000	$ 42,435,000
Total Manufacturing Labor Costs	53,101,000	75,168,000
Total Offer Direct Costs	10,364,000	16,411,000
G&A	6,762,000	---
Profit	7,396,000	---
Total Airframes Cost	$114,748,000	$134,014,000
Technical Data	1,228,000	2,082,000
Repair Parts & Special Tools	2,620,000	3,922,000
Training Aids	703,000	456,000
Non-Recurring Tooling & Development	---	2,220,000
G&A	3,199,000	15,787
Profit	589,000	(loss) (10,004)
Total Contract Ceiling	$123,087,000	$148,477,000

[a]DD Form 1558, Cost Information Report Contract Cost Data Summary, Bell Helicopter Company, P. O. Box 482, Fort Worth, TX, 76101, as of 30 June 1968, dtd. 13 August 1968.

[b]DD Form 1558, dtd. 10 August 1973.

D. SUMMARY

With the completion of the Bell contract on June 30, 1973, the Army had procured 1,071 OH-6A helicopters from Hughes and 2,200 OH-58A helicopters from Bell. All were procured by means

of the two-step invitation for bid competitive process. The OH-6As were procured by use of a firm-fixed-price contract. The OH-58As were procured by use of a fixed-price contract with escalation provisions. In the case of the OH-6A, the government purchased 1,071 helicopters from Hughes for $21M at $19,860 per airframe. The government's corresponding estimate was $30M at $28,204 per airframe. As for the LOH follow-on procurement of the OH-58As from Bell, the government purchased 2,200 helicopters for $117M (contract award price) at $53,450 per airframe. The government's corresponding estimate was $103M at $46,853 per airframe. Bell's contract bid price was $14.5M more than the government's estimate.

Competition in the LOH procurements was intense. At stake was the domination of the light helicopter market in the United States. As events evolved, the government benefited by using competition to procure its LOHs although two helicopter types entered the inventory.

The Army procurement of the LOH suggests several lessons which may be advantageously incorporated into the future procurement of complex weapon systems and equipment:

- **Plan for the procurement of the total expected requirements and explore feasible alternatives before committing to one plan of action.**

The Army only contracted for a fraction of its total planned requirements under the first competively awarded contract. Without reintroducing a second firm and its model, the Army was confronted with negotiating a follow-on contract with a sole-source producer. The difference in the prices of the first and second contracts suggests that a single multi-year contract for the total planned requirements with appropriate options would have been less costly to the government.

In the initial stage of selecting the research and development competitors the government did not negotiate for the eventual delivery of a production quality TDP, technical assistance, a second source, or rights in data. Later quotes on the TDP offered by Hughes were so high that they effectively precluded second-source production of Hughes' design.

- **Give all competitors, especially those new to the market, realistic specifications.**

Hughes won the initial contract with a design that met the original specifications. However, it was not very flexible with respect to increases in flying weight. Such weight increases are rather common to such aircraft, but apparently this was not anticipated by Hughes. Initial costs might have been greater, but much of the unanticipated production cost increase might have been avoided with a more flexible design. Hughes was also placed at a relative competitive disadvantage when the engine size was allowed to increase in order to accommodate the increase in weight of the Bell machine.

- **Unplanned increases in desired purchases can be expensive, especially if required early in the production build-up phase.**

An increase in the production rate requires faster expansion of capacity and training of new workers, which is more costly earlier in the production build-up phase. Negotiations with a sole-source producer after the competitive contract has been awarded is, of course, likely to lead to a higher price also.

- **Design and price competition to performance specifications may be a desirable alternative to pure price competition for production of an identical model.**

Experience with the procurement of the LOH illustrates this point. After Hughes won the original production contract, it quoted $26M as the price for a technical data package and for rights in data. Thus, establishment of a second source for pure price competition would have cost at least $26M and probably more for direct technical assistance, learning buys, and extra testing. In contrast, the price which the government paid for the original development contracts with Bell ($5.98M) and Hiller (6.54M) was less than the Hughes quote for the TDP. Although the R&D contract prices were possibly lower than actual costs (a buy-in) for competitive reasons, it does demonstrate at least the potential of design plus price competition as an alternative to pure price competition.

Design and price competition is the method which the Army ultimately used for the second procurement of the LOH. Hughes' quote for the TDP and the rights in data was prohibitively expensive; rather than accepting sole-source negotiation for the second contract, the government reintroduced Bell as a second candidate to provide a LOH of its own design. Bell eventually won the new contract so that two different models were deployed to the user commands. By deploying one model east and one model west of the Mississippi River, the extra costs of logistics and maintenance--often regarded as prohibiting design and price competition to performance specifications--were circumvented. It should also be noted that Bell remained a viable producer after losing the first competition because it could produce for the commercial market for helicopters. Such commercial market alternatives are not always available for producers of other systems procured by the Department of Defense. However, the case does confirm the desirability of having commercial and military requirements close together.

APPENDIX F

STYLIZED EXAMPLES

STYLIZED EXAMPLES

A series of numerical examples are used to illustrate the sensitivity to various assumptions of the estimated savings attributed to the introduction of competition. The numbers are not those of an actual procurement, but they do represent observed experience with several different systems and components.

First, the base case of sole-source production is presented. A second source is then established with the use of a technical data package (TDP) to transfer technology. Next, the production schedule is stretched over time to preserve a greater volume for competitively awarded contracts. Then it is assumed that the second source manages to obtain production cost parity after producing only 30 percent of the sole-source volume. Finally, the impact of introducing a second source two years earlier by using the leader-follower procurement method of transferring technology is examined.

The estimated net savings of each of the examples should not be interpreted as implying that competition is or is not cost effective. Rather the concern is with impact of *changes* in the assumptions on the estimated net savings. Some of the assumptions, such as the level of non-recurring costs, are somewhat arbitrary and can be changed without negating the comparisons. Delaying the build-up in production rate, the second source experiencing a lower first unit cost and gaining production cost parity, and establishing the second source earlier by the use of leader-follower procurement rather than a production validated TDP are realistic possibilities and are the main point of this exercise.

Figure F-1 represents the sole-source production experience. The graph is not drawn to scale, and the progress curve is depicted as linear for ease of exposition only. A total of 8400 units are procured over seven years according to the schedule at the bottom of the graph. Production costs are incurred according to the unit cost progress curve:

$$UC = 198{,}129 \ V.^{-.2} \ .$$

The exponent, -.2, corresponds to a slope of 87 percent which is approximately average for previous sole-source procurements of missiles and major missile components. The total implied production cost found by integrating this curve over 8400 units is $3.41 M units.

Figure F-2 represents the use of the TDP to establish the second source. The TDP must first be validated by volume production, prepared by the original source, and then examined for accuracy by the government or another third party before it can be used for the selection of and transfer of technology to a second source. Therefore it is assumed that production with the second source is not initiated until the third year.

The second source produces 50 units which are destroyed in first article testing. Of the annual procurement, 100 requirements are transferred in the third year and 400 are transferred in the fourth year for production by the second source. It is assumed for this case that the second source has the same progress curve cost experience as did the original producer. The implied cost of producing the 50 first articles is $5.7 million and the extra cost of transferring part of the annual production to the second source is $3.8 million in the third year and $9.9 million in year four. The extra cost results because the first source no longer goes as far down it's cost curve because of the reduced volume and because the second source, with even less cumulative volume, is a higher cost

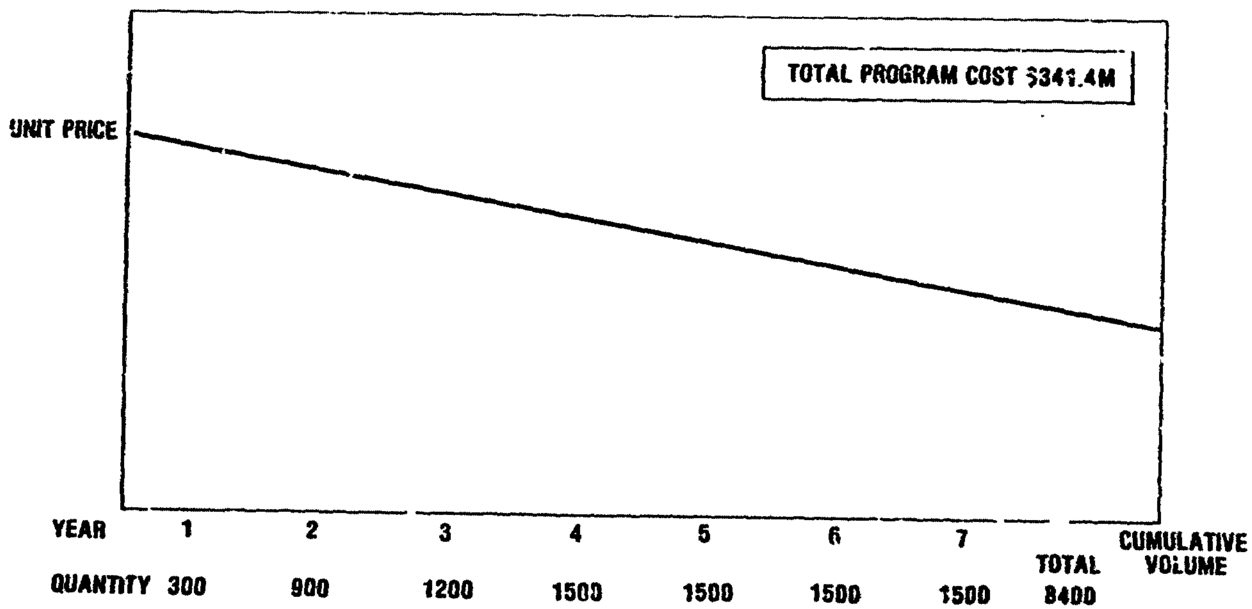
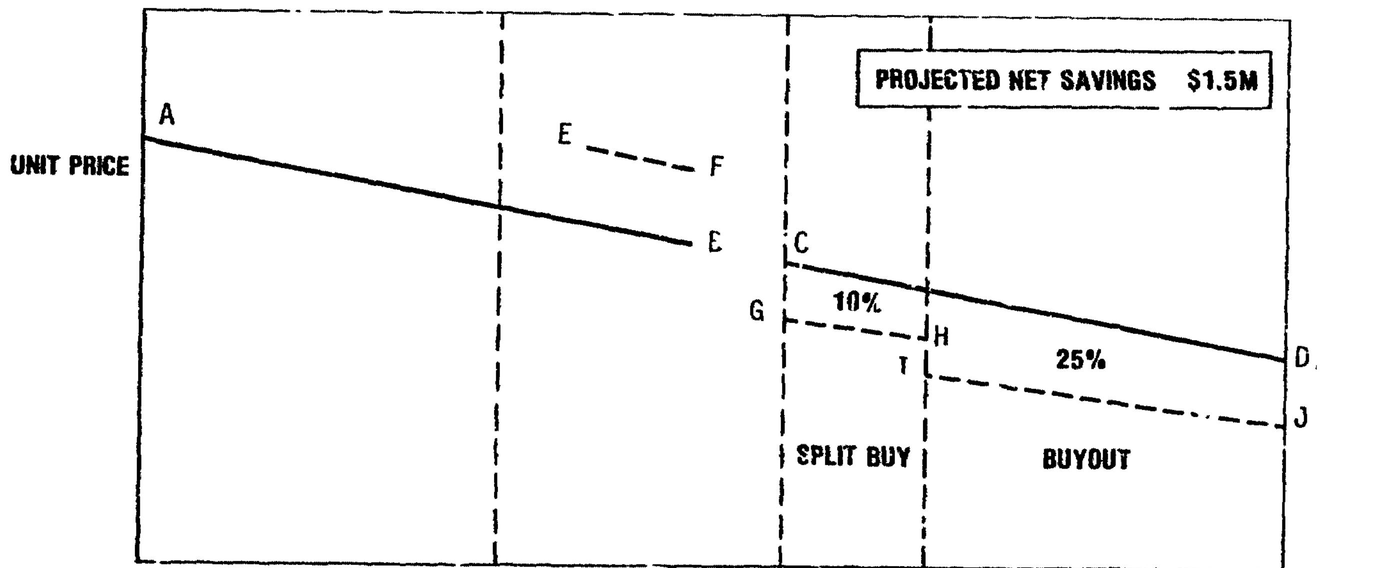


Figure F-1. ORIGINAL SOLE SOURCE PRODUCTION SCHEDULE, 87% SLOPE



YEAR	1	2	3	4	5	6	7	TOTAL
FIRST SOURCE QUANTITY	300	900	1100	1100	1500	1500	1500	8400
SECOND SOURCE QUANTITY			150	400				
CHANGE IN PROCUREMENT COSTS			$ -3.8M $ -5.7M	$-9.9M	$5.5M	$13.0M	$12.4M	
NON-RECURRING COSTS								
TDP -	-5.0M							
OTHER	-5.0M							

Figure F-2. NEGOTIATED COMPETITION WITH TDP, ORIGINAL SCHEDULE

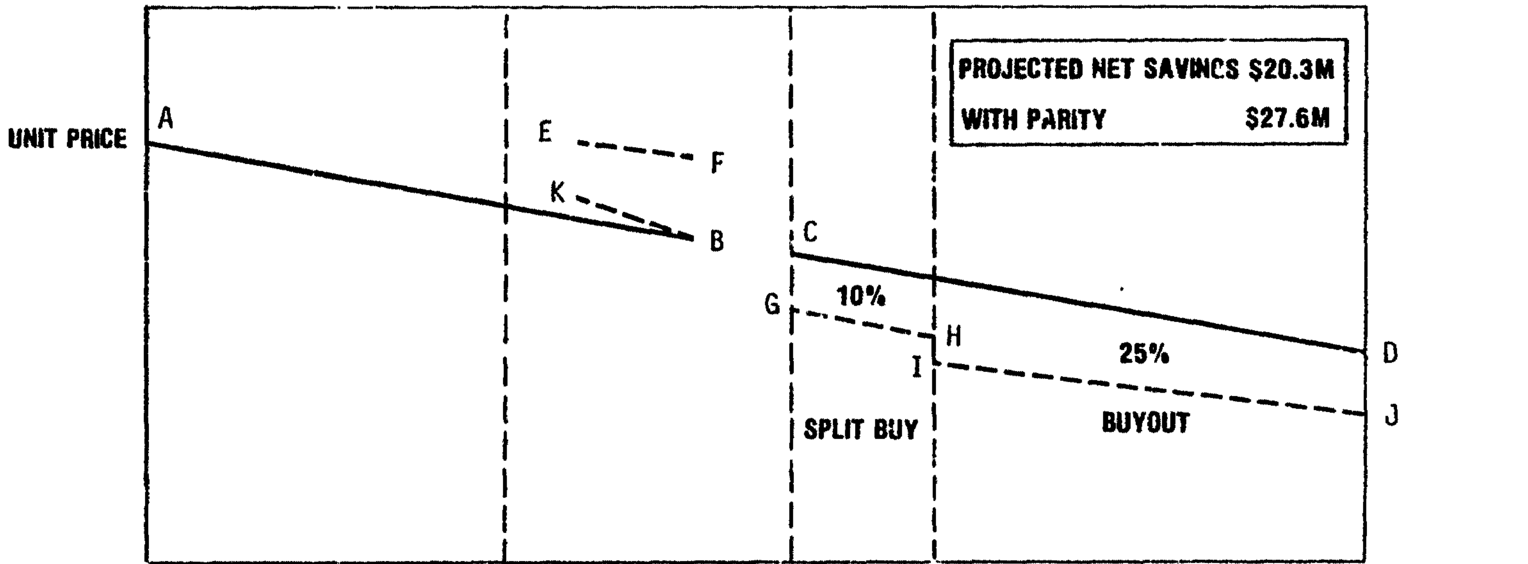
producer. The non-recurring costs are specified for this example as $5.0 million to acquire a usable TDP and $5.0 million for the costs of such things as first article testing and special tooling and test equipment.

All the extra costs of establishing a second source are shown as negative at the bottom of Figure F-2, and eventual savings are shown as positive numbers. It is assumed that a split-award competition is held in year 5 where the winner receives the largest share of the award; the assumed savings for that contract are 10 percent of the planned sole-source procurement cost. The fifth and sixth year contracts are competed together as a winner-take-all multi-year contract at a savings of 25 percent relative to the projected sole-source cost.

A simple summation of the annual increments to costs yields a net savings of only $1.5 million. The corresponding rate of return is approximately 4.5 percent. If this example represented an actual system, competition would not be introduced for financial reasons alone.

In Figure F-2, the solid line represents the projected sole-source progress curve. The space between B and C indicates that part of the third and fourth year requirements are no longer produced by the original firm. The dashed line EF represents the cost of second-source production of the 50 first articles and the 500 units transferred from the first source. Finally the dashed lines GH and IJ represent the post competition lower production cost experience.

The first example depicted in Figure F-3 assumes the same production cost experience during years three and four for the second source (dashed line EF). The only difference with this example is that the production schedule is stretched by reducing production during the first four years and adding an extra year of production to make up the difference. There are two results



YEAR	1	2	3	4	5	6	7	8	TOTAL
FIRST SOURCE QUANTITY	100	300	500	800	1500	1500	1500	1700	8400
SECOND SOURCE QUANTITY			150	400					
CHANGE IN PROCUREMENT COSTS			$-3.0M -5.7M	$-8.1M	$0.0M	$13.9M	$13.1M	$14.2M	
NON-RECURRING COSTS			-10.0M						
CHANGE IN PROCUREMENT COSTS IF PARITY REACHED			-1.5M -4.8M	-3.2M					

Figure F-3. NEGOTIATED COMPETITION WITH TDP, STRETCHED SCHEDULE

of this change: first, a greater volume of production is awarded under the pressure of competition; second, because the original source has not proceeded as far down the progress curve, the net cost of transferring 500 units or production to the second source is reduced. The impact of stretching the production schedule is substantial. The projected net savings increase to $20.3 million dollars.

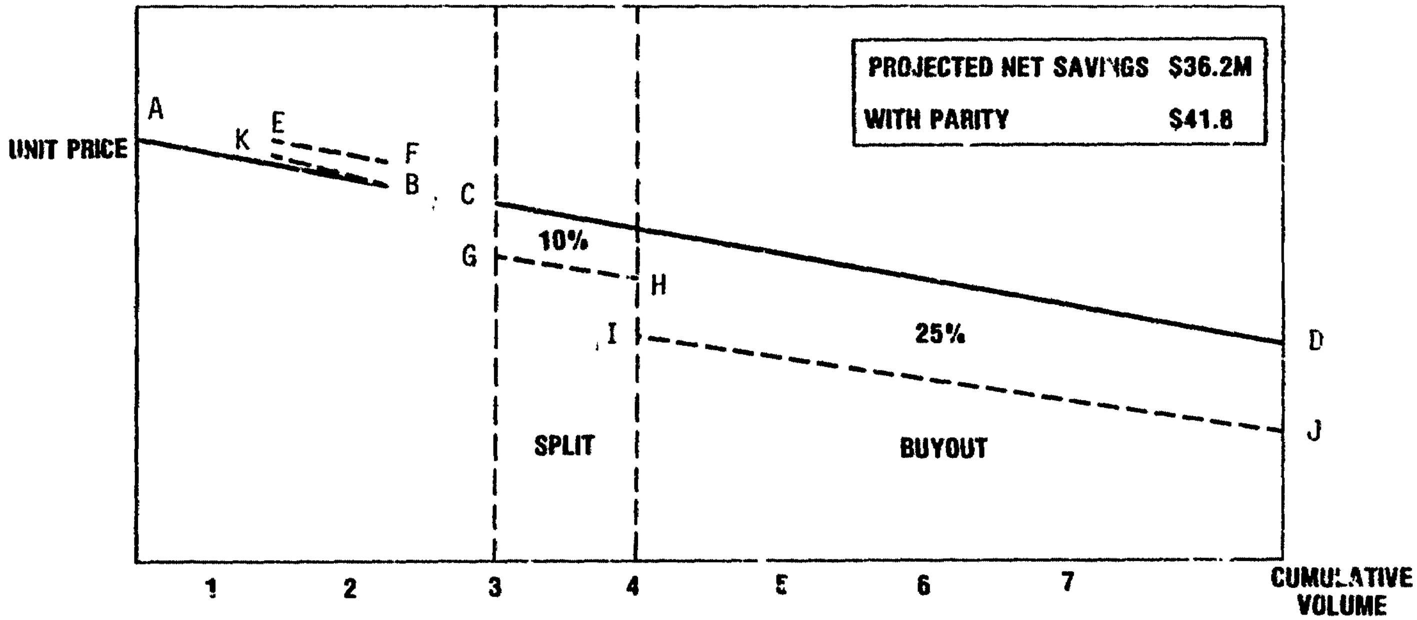
In the previous two examples the production costs of the second source during the third and fourth years have been specified according to the same progress curve as that of the original source. Experience with actual procurements indicates that a second source often begins production at a lower first unit cost and manages to attain production cost parity with the first source at a fraction of the cumulative volume.

To incorporate those observations it was explicitly assumed that the second source begins production at a unit cost equivalent to the second unit produced by the original producer, rather than the first unit, and that the second source gains production cost parity after producing 30 percent of the sole-source volume. The assumption is depicted by the dashed line AB; the implied second source progress curve is

$$UC = 172{,}481.31\ V^{-.2138} \quad .$$

If the second source produces according to this curve, the net cost of splitting production between the two contractors is reduced and the net savings increase to $27.6M as a result. The corresponding rate of return is 30 percent.

Figure F-4 depicts the case where second source production is initiated in the first year rather than the third, and competition begins in the third year rather than the fifth. This is presumed possible by the use of the leader-follower method of procurement which allows the selection of a second source before the TDP is validated by volume production and



YEAR	1	2	3	4	5	6	7	TOTAL
FIRST SOURCE QUANTITY	300	661	1200	1500	1500	1500	1500	8400
SECOND SOURCE QUANTITY	50	239						
CHANGE IN PROCUREMENT COSTS	$-5.7M	$-5.7M	$+5.3M	$14.9M	$13.7M	$13.0M	$12.4M	
MARKUP 25%	-1.4M	-4.3M						
OTHER NRC	-6.0M							
WITH PARITY	-4.7M	-2.1M						
MARKUP 25%	-1.2M	-3.5M						
OTHER NRC	-6.0M							

Figure F-4. LEADER COMPANY COMPETITION, ORIGINAL SCHEDULE

which provides for direct technical assistance from the leader to the follower company.

A major advantage of leader-follower is that two more years' production is subjected to competition with a resultant increase in savings. The net cost of shifting production to a second contractor is also less because the first source has not proceeded as far down the progress curve, so the initial cost advantage relative to the second source is less and because a smaller pre-competition quantity is required by the second source to gain production cost parity.

For the examples illustrated in Figure F-4 the change in procurement costs, both start-up costs and savings, are calculated as before. As compensation for accepting responsibility for delivery of the pre-competition production by the second source, the first source is awarded a 25 percent mark-up on the production costs of the second source. Other non-recurring costs (NRC) are specified as $6 million.

With the original production schedule the projected net savings are $36.2 million if the second source has the same progress curve as the first source during the pre-competition production period. If the second source starts production at the cost of the second unit of the sole-source's production, and achieves production cost parity at the end of two years, after producing 30 percent of the volume of the original source, its progress curve is

$$UC = 172{,}481\ V^{-.2179}$$

and the projected net savings are $41.8 million. That corresponds to a rate of return of about 40 percent.

The numerical examples presented in the Figures, with additional information, are summarized in Table F-1. TDP refers to the use of negotiated competition and transfer of

Table F-1. COMPARISON OF EXAMPLES

PRODUCTION SCHEDULE	METHOD	PARITY	SECOND SOURCE LEARNING QUANTITY	NET SAVINGS (MILLIONS)
ORIGINAL	TDP	NO	550	$ 1.5
STRETCHED	TDP	NO	550	$20.3
STRETCHED	TDP	YES	550	$27.6
ORIGINAL	L-F	NO	550	$31.3
ORIGINAL	L-F	NO	289	$36.2
ORIGINAL	L-F	YES	289	$41.8
STRETCHED	L-F	NO	104	$57.7

technology by means of a technical data package, with second-source production beginning in the third year and competition beginning in the fourth year. L-F refers to leader-follower procurement where the second source begins production in the first year and competition starts in the third year.

Table F-2 lists the post-competitive annual gross savings according to various assumptions. The second column lists the savings as used to construct the leader-follower example assuming the original production schedule. A split-award competition is held in the third year from a savings of 10 percent of sole-source costs. An all-or-nothing competition is held for a multi-year contract for the last four years' production at a savings of 25 percent.

In the third column it is assumed that the split-award competition is not held until the fourth year and the buy-out does not occur until the fifth. In column 4, annual split-award competitions at a gross savings of 10 percent are assumed. Column 5 shows the annual cost of a 5 percent license fee. In some situations that fee might be paid to the original developer-producer as compensation for proprietary data and for technical assistance provided to establish the second source. The last four columns repeat the previous four, but with the stretched production schedule which saves more of the production volume for the post competition period.

Any number of examples can be worked out using the savings assumptions illustrated in Table F-2 and by making other assumptions regarding the cost and time required to establish a second source, and the expected gross savings in price for contracts awarded competitively. However, the main conclusions of this appendix are relatively robust to reasonable changes in the assumptions. Projected net savings from introducing competition are substantially improved by:

Table F-2. POST COMPETITION

Annual Gross Savings
(millions)

	ORIGINAL SCHEDULE				STRETCHED SCHEDULE			
YEAR	BASE EXAMPLE	LAGGED	ALL SPLIT AWARD	5 PERCENT LICENSE FEE	BASE EXAMPLE	LAGGED	ALL SPLIT AWARD	5 PERCENT LICENSE FEE
1	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—
3	$ 5.3	—	$ 5.3	$ 2.7	$ 3.2	—	$ 3.2	$ 1.6
4	14.9	5.9	5.9	3.0	13.7	$ 5.5	5.5	2.8
5	13.7	13.7	5.3	2.8	15.1	15.1	6.0	3.0
6	13.0	13.0	5.2	2.6	13.9	13.9	5.5	2.8
7	12.4	12.4	5.0	2.5	13.1	13.1	5.3	2.7
8	—	—	—	—	14.1	14.1	5.7	2.9
TOTAL	$59.3	$45.0	$26.9	$13.3	$73.1	$61.7	$31.2	$15.8

(1) Delaying the build-up in production rate;

(2) Establishing the second source as early as possible;

(3) Starting the second source at a lower first unit price and achieving production cost parity.

The sensitivity to variations in these dimensions should be carefully considered when analyzing the impact of competition on an actual procurement.

APPENDIX G

ISSUES INVOLVED IN INTRODUCING PRICE COMPETITION FOR REPROCUREMENT

ISSUES INVOLVED IN INTRODUCING PRICE COMPETITION FOR REPROCUREMENT

A. INTRODUCTION

As part of our effort to determine criteria for the selection of systems for the introduction of competition, we attempted to determine with respect to competitive reprocurement--

- How candidate systems are presently selected;
- The types of problems frequently associated with the introduction of competition;
- System characteristics or other conditions which inhibit the use of competition;
- Perceptions of the benefits of and attitudes toward the desirability of more price-competitive procurements.

Information on these subjects was obtained through interviews with personnel in the materiel commands involved with the procurement of weapon systems. The issues covered include:

(1) Program stretchouts

(2) Cost of initiating competition

(3) Risk of delays, defaults, and reduced liability

(4) Technical data problems

(5) Inability to use multi-year contracts

(6) Inadequate incentives

(7) Non-price benefits of competition

(8) Alternatives to pure price competition

(9) Competitive reprocurement and design to cost, design to life-cycle cost, and reliability improvement warranty programs

(10) The need for flexibility.

Although each of these issues is discussed separately herein, they are interdependent. For example, the risks involved are partly a function of technical data inadequacies; but technical data problems and other risks incumbent in competition can be reduced with increased start-up expenditures, thorough validation of the technical data package, and careful qualification of the second source. It should also be understood that this discussion presents a distillation of our impressions gleaned from examination of previous case studies and a review of the literature as well as from the interviews. It is not merely a verbatim report of our discussions.

The major findings of this phase of the study can be summarized as follows:

(1) Competitive reprocurement will not be introduced to all systems and components for which it is feasible under present policies and practices. Reasons include adverse incentives and attitudes toward incurring the initial cost and toward the risk of delay for the chance at a future reduction in system price; constraints on funds and personnel required for the initiation of competition; and procurement regulations which tend to restrict choice of competitive techniques.

(2) There is a tendency to use formally advertized competition more often than is appropriate. It is faster, lower cost, and makes available more procurements for small businesses. However, it is risky, especially when the specifications are not firm and the technical data package is inadequate. Once an exception to formally advertized competition is obtained for a particular procurement, other methods of initiating competition are not routinely considered.

(3) Early planning can reduce costs and delays required to effect transfer of technology and can increase the actual production volume subject to competition.

(4) Non-price aspects of competition are significant and may be the deciding factor for or against the introduction of competition. Inadequate technical performance of the original producer, fear of reduced reliability of delivery delays, the impact on the

industrial base, and the impact on logistics and maintenance costs have all been deciding factors.

(5) Production to form, fit and function, and performance specifications may ease the burden of technology transfer and be an attractive alternative to pure price competition.

B. PROGRAM STRETCHOUTS

Introducing a second source for production requires a significant increase in the production lead time beyond that required by the presently active contractor. The extra time is required to screen and competitively select the second source, to acquire and install tooling, for related pre-production preparation of facilities, and to produce and test first items for qualification. The extra time required varies with the firmness of the design and the complexity of the technology that must be transferred. For items with firm technical specifications and drawings, a formally advertized competition may be feasible. Typically the extra lead time required for such competition in the past has been in the range of 10 to 15 months.

More complex items may require technical assistance from the original contractor to the second source to accomplish the transfer of technology; the second source may require substantial production experience before meaningful competition with the original producer is possible. Under the leader-follower method, which has been used to introduce competition for the procurement of Army missiles, up to 39 months has been required between the selection of a second source and the all-or-nothing competitive buy out.

Such stretchouts in production can lead to delays in deployment of the system with an obvious, but often unquantifiable, impact on the readiness of the user command. If the competed item is a subcomponent, it can still interrupt the production and delay the delivery of the whole system. Storage

of incomplete items and idle production lines can significantly increase contractor's costs and, ultimately, the government's costs.

An obvious solution to the delivery delays is concurrent production by the original source. While reducing the problem of delays, concurrent production introduces other difficulties. For one thing, the more the original source produces while the second source is developed, the less production is actually subject to the pressure of competition. Reduction in the rate of production of the original contractor in an effort to save volume for post-competition contracts may result in higher unit costs during the interim period.

Increases in lead time required to develop a new source, combined with the uncertainty of when and if the new contractor's product will pass first item testing make planning and budgeting all the more difficult. Funding for two contractors may be difficult to obtain. Plans to increase production tooling for a higher production rate may also be inhibited by a long and uncertain development of a second source. Finally, the longer it takes to develop a second source, the longer it takes to obtain a pay back of the funds expended to initiate competition. Use of such techniques as leader-follower procurement or fusion-fission discussed in Chapter V may help reduce the required lead time of technology transfer of complex items.

C. FUNDS AND PERSONNEL REQUIRED TO INITIATE COMPETITION

A major theme of the first stage of this study was that introducing competition for reprocurement will often require a substantial initial outlay of funds that can only be recovered at a later date in the form of reduced unit prices for competitively awarded production contracts. This was confirmed in the interviews and case studies. As well as decreasing expected net savings and thereby reducing the attractiveness of competition, the requirement for initial expenditures may establish another

obstacle. Funds for initiating competition are not always included in the procurement budgets. When they are included, they are prime candidates for deletion or transfer in time of budgetary austerity. Thus competition may not be introduced for some systems simply for lack of front-end funds.

Required expenditures vary considerably from system to system. They typically begin with the acquisition of the technical data package (TDP) and possibly the rights to use patents or proprietary data. Technology transfer may also involve payment to the original producer-developer for technical assistance provided to the second source. Special tooling and test equipment with no application to other systems may be financed directly by the government. Extra testing required to qualify the items produced by the second source incurs both the production cost of any items which are destroyed during the test and the cost of the test and evaluation procedure itself.

Only the net cost of starting a second source should be considered. For items not destroyed in testing, the cost of an educational buy awarded to the second source minus the prospective cost of sole-source production of that quantity is attributable to competition, not the total cost of the contract. If a second source is initiated to expand the production base as well as to obtain competition, then only the cost of setting up production in the facilities of the second source net of the planned cost of expanding production capacity of the original contractor should be attributed to introducing competition.

A related, but sometimes independent, constraint is insufficient qualified personnel to implement competition. While competition can be expected to reduce the eventual requirements for government personnel to negotiate and monitor contracts, the selection and qualification of a second source may initially require more personnel time. This may be especially important for the break-out of subcomponents on large systems which

requires technical evaluation of the feasibility of break-out for each subcomponent. Components broken out for competition and then provided to the prime contractor as government furnished equipment (GFF) may require extra monitoring and technical assistance for the subcontractor which was formerly provided by the prime contractor. If a program manager can neither reassign personnel from other tasks nor temporarily obtain new personnel, opportunities for introducing competition will be lost.

D. RISKS OF DELAYS, DEFAULTS, AND REDUCED RELIABILITY

The history of competitive reprocurement is replete with examples of delivery delays, defaults of the second source, and at least occasionally, reduced reliability of the delivered equipment. The result of these problems is reduced readiness of the using commands. It is difficult to assign a cost to such delays, but using commands pressure program offices to ensure timely delivery of the systems. Fear of such delays undoubtedly discourages the use of competitive procurement when otherwise feasible.

For example, problems may result when components of a system are broken out by the government and set aside for competition among small or minority-owned businesses. Delays in delivery of these items as GFE to the prime contractor then impact on the whole system. Production interruptions and inventory buildups of partially fabricated items directly raise the contractor s cost and, ultimately, the cost to the government of procuring the system. Another source of risk is undertaking formally advertised IFB competitions on items whose complexity is underestimated and for whose production the second source, selected by permissible processes, may be underqualified.

A certain amount of difficulty is to be expected when competition is introduced. A design, sometimes at the frontier

of technology, is transferred from the firm that developed the item, but which may have limited production experience with it, to a firm with no experience with the particular item. It may generally be expected that the more complex the system, the more difficult the transfer of technology and the greater the risk of delay and default from introducing competition. However, there are several techniques available for introducing competition so officials with responsibility for procurement must make a choice: more complex systems can be competed and the risk of delivery delays and deterioration in system performance and reliability reduced by the use of more elaborate, but more costly and time consuming, techniques.

While difficulties can arise with the use of any of the techniques, experience indicates that otherwise avoidable problems are frequently encountered because of the inappropriate use of the simplest technique, formally advertised invitation for bid (IFB) competition. The tendency to over-use formal IFB competition results from several factors. First of all, it is government policy to use IFB competition whenever possible. Use of negotiation with a sole-source contractor or use of negotiated competition requires appeal to one of the seventeen exceptions listed in the Defense Acquisition Regulations (see Chapter V). Second, it is faster and requires little or no government funds and less government supervision to initiate IFB competition than other techniques. Finally, there is pressure to expand the share of the procurement budget awarded to small and minority-owned business. Use of techniques that require technical proposals and put more emphasis on the evaluation of technical and financial capability of the contractor make it more difficult for small businesses to compete.

The essence of IFB competition is that:

(1) It is assumed that the specifications of an item are well defined and are an adequate guide for the transfer of technology to the second source.

(2) Evaluation of the technical and financial qualifications of the bidding contractors is limited.

(3) Contracts are awarded on a fixed-price basis.

The problems with IFB competition arise when the assumptions regarding the firmness of the specifications and the adequacy of the TDP are violated; because of inadequate screening of candidates for technical and financial capability to produce and deliver; and because of limited capability of the government to provide technical and financial assistance to small firms when they encounter problems with production.

As discussed in the following section, the TDP is never complete. Information on manufacturing processes and plant layout, often regarded as proprietary, is not included. Items of information may be excluded because they are regarded as common practice by one firm, although not by another; because of errors due to design changes, oversight or lack of incentive on the part of the initial contractor; or because of the difficulty of managing a highly detailed TDP. Adequacy of a TDP is probably never total; it is a responsiblity of its user to fill in the blanks and to provide engineering support to solve any unexpected problems.

The supposed firmness of the specifications and the relatively low unit cost and low complexity of the items offered for IFB competition encourage bidding by small, new, and sometimes marginally qualified firms. Those firms, referred to as loft manufacturers because of the size and simplicity of their facilities, are able to bid lower prices because of less overhead than larger, more experienced firms. They frequently submit unrealistically low bids in order to win the competition. This practice, known as "buying in," occurs for reasons of business strategy, desire to enter a new market, or to cover temporary excess capacity; because of underbidding due to inexperience, error, or excessive optimism; or because the contractor expects to "get well" on the extra revenue generated by

engineering change orders or legal claims submitted because of deficient data on government furnished equipment.

Such firms, if at least marginally capable of producing the item, cannot be excluded from bidding. Further, even if a bid is below actual cost, government policy does not permit its rejection. For balance it should be pointed out that in many cases buy-in prices can be quite beneficial to the government. However, if a small firm with limited resources and minimal engineering capabilities wins a competition with a buy-in bid and then runs into unexpected problems, delays and defaults result. Also the "buy in and get well on change orders" strategy tends to drive the more well established and technically capable firms out of the market. That, of course, could have adverse effects on the long-run viability of the industrial base for particular group of systems.

When a small Joft manufacturer experiences problems with production, whether financial, technical, or both, the possible responses of the government are limited. For most items, the government has insufficient capability and flexibility to provide technical support to a troubled contractor. In fact, providing extra financial or technical assistance to the winner of a firm-fixed-price contract violates the spirit if not the letter of the regulations regarding IFB competitions. Such assistance would likely be challenged as inequitable by losers of the competition. On the other hand, if the government chooses to get tough with respect to assistance and contract extensions, and to resist engineering change orders, then it faces the prospect of delay, default, and even bankruptcy of the contractor. Another response to delivery delays is to hold a competition for another contract to replace the contract in delay or default. This move has been foiled when the new award is won by the firm which failed to deliver on the first contract. That is especially likely to occur when the bidder is qualified to receive certification from the Small Business

Administration (not the Department of Defense) as competent to undertake the new contract. Finally, if requirements of users are sufficiently pressing, the government may forego competition of any sort and award a negotiated contract to the original producer, often at a premium over the original sole-source offer, in order to ensure delivery.

Besides the problem of defaults and delays in delivery, product reliability sometimes decreases as a result of competition and a change in contractors. Such reductions in reliability are not always detected during first article and acceptance testing; rather, they show up after deployment in the user commands. Such reductions in reliability are attributed to differences in the processes by which the article is manufactured by the new contractor as compared with the original contractor. Processes are generally not included as part of the TDP and they generally differ between firms. The reliability problem is likely to be accentuated by the competitive pressure to substitute less expensive materials and otherwise cut corners in order to keep costs down.

In fairness it should be added that reduced reliability is not a necessary result of price competition for reprocurement. In fact, competitive procurement can result in improved technical performance and reliability. Those issues will be discussed further in this Appendix.

E. TECHNICAL DATA PACKAGES--NECESSARY BUT OFTEN INSUFFICIENT

The major hurdle for successful price competition is the transfer of the capability to produce an item from the original developer-producer to a second source. The cornerstone of such a technological transfer is the technical data package (TDP) which is almost always necessary but frequently insufficient to accomplish the transfer. The adequacy of the TDP for any particular system or subcomponent transfer is a function, at

least partly, of the complexity of the technology involved, the incentive of the original contractor to provide good data, the ability of the government to manage and validate the TDP, and the technical and engineering capability of the second source to fill in the blanks. The history, problems, and philosophy of the government's technical data policies are well documented elsewhere.[1] This section is intended to be only a summary of the highlights which were emphasized in the interviews with personnel of the Armed Services.

The TDP is never a complete document; process data, especially when they are regarded as a proprietary trade secret, are usually omitted. Such claims to proprietary information are especially prevalent among subcontractor vendors. Even when a whole system is competed, the new prime contractor may have to return to an original subcontractor in order to acquire a particular part. Sole-source contractors, of course, have every incentive to over extend their claims to proprietary and patented data, to avoid timely delivery of the TDP, and to avoid taking great pains to ensure the accuracy of the package. Any delays and problems obviously enhance their competitive positions.

Even with the proper incentives for the original sources, the problems are substantial. One is the sheer magnitude of the detail and number of drawings involved. At some point a trade-off must be made between completeness of detail on the one hand and cost and manageability on the other. For the systems that the DoD procures, design changes are frequent, especially early in the production phase. It is difficult to keep the TDP accurate and up to date in those circumstances.

Policies and attitudes regarding the acquisition of TDPs vary between the Services, and even between commands in the same Service. Those differences no doubt reflect the experience and

[1] Gregory A. Carter, *Directed Licensing: An Evaluation of a Proposed Technique for Reducing the Procurement Cost of Aircraft*, R-1604-PR, RAND Corporation, Santa Monica, CA, December 1974.

type of system procured by each command. The Army acquires TDPs much more routinely than the other Services. At least the Army Missile Readiness Command (MIRCOM) appears to have considerable in-house capacity to validate and manage TDPs. The stated policy of the Air Force is to acquire a TDP only when there are definite plans to introduce a second source. That policy undoubtedly reflects their experience with high priced but low volume systems for which competition is regarded as impractical and for which acquisition of a production quality TDP is a waste of funds. This policy may have resulted in a reduced capability of the Electronics System Division (ESD) and the Aeronautical Systems Division (ASD) to manage and validate TDPs, and, consequently, to undertake competitive reprocurement.

If a TDP is to be acquired, early negotiations for its cost and for "rights in data" are important. Contractor claims regarding the value of patents and proprietary data and the cost of providing the TDP are sensitive to the alternative sources available and the general bargaining position of the government. Of course, the government's negotiating strength is much better during the R&D phase, when alternative contractors are still available or the system has not been approved for production, than it is after a single source is firmly entrenched in production. If the introduction of competition is uncertain, early negotiations of an option to acquire the TDP provides a limited form of insurance.

Steps can and have been taken to improve the quality of the TDP and otherwise improve the technology transfer process. A TDP generated during the research and development (R&D) phase may not be adequate for production. Further, many design changes take place during initial production. Postponing TDP delivery until after the original source gains production experience and is able to incorporate the many early changes in the drawings can improve the quality of the TDP considerably.

Because of its inadequate technical-production expertise, the Department of Defense (DoD) agency responsible for procurement of a particular system is unlikely to be able to examine a TDP for errors. However, it may engage a company, which agrees not to compete for any production contracts, to independently test and validate the TDP as an acceptable guide for production. The Army Missile Readiness Command (MIRCOM), for example, often contracts with a small minority-owned business to validate TDPs of components broken out for the small business set-aside program.

Another tactic to mitigate the problems involved with technology transfer is to acknowledge that the article to be procured is not sufficiently well specified to support an IFB competition and use negotiated competition instead. The techniques available for negotiated competition are discussed in Chapter V but the advantages can be briefly summarized. More effective screening of candidates with respect to their technical, managerial, and financial capabilities is possible. The second source can gain production experience with the item before engaging the original developer-producer in direct price competition for production contracts. Finally, direct technical assistance from the original developer-producer to the second source can be negotiated.

The methods used to improve the quality of the TDP and the effectiveness of technology transfer all decrease the risk of delay and default to the government. They, in fact, make competition feasible for some systems where it would otherwise be prohibited by the inability to transfer technology. However, each of the techniques increase cost, time, or both, required to effect the transfer. The extra cost and time required may in some situations more than cancel the expected benefits from competition. The cost-time-risk trade-off expands alternatives but increases the complexity of the decision of whether and how to introduce price competition for production.

F. LONG TERM CONTRACTS: THE APPEAL AND THE PROBLEMS

In some situations, the annual procurements may be insufficient to support two firms at efficient sustainable rates of production. Also, the maximum realization of the benefits of economies of scale, and the progress curve effect may only be realized by awarding all production to one firm. With perfect foresight the lowest price for the government would be achieved by competition for an all-or-nothing competition for a multi-year contract. In reality, program instability, general economic instability, and the impact of technological change inhibit the use of such contracts.

Program instability refers to the inability of the Department of Defense to firmly commit funds for multi-year contracts. All plans and commitments are subject to annual appropriation of funds by Congress and government financial liability to the contractor is limited if the program is cancelled. The government budgeting process and the nature of the systems procured by the Department of Defense (DoD) make it difficult to forecast future requirements for a particular item.

It is never certain when a new development will reach production phase or when a change in threat assessment will result in the obsolescence of a particular system and a reduction or cancellation of the procurement. Increased procurement of other systems, expansion of other DoD programs, or a reduction in the DoD budget after adjusting for inflation, can all result in reduced funds available for a particular system. Thus the commitment to the long term contract becomes rather asymmetric. Government demands delivery, but cannot fully guarantee what its future requirements will be.

Private firms are also reluctant to incur the risk of a long term contractual obligation with the government at a fixed price because of the instability of the supply and prices of

their inputs. Escalation clauses which adjust contracts for inflation are regarded as insufficient protection from external risks. Also, lucrative commercial opportunities reduce the appeal of long term government contracts. Several examples are cited in the following paragraphs.

At the present time there is a shortage of aluminum of the quality required for airframes and certain other components. Required production lead times have been increased in order to acquire the aluminum, and contractors are unwilling to make long term quotes on price or delivery date of any item requiring the material. The shortage has variously been attributed to the increased demand for and production of commercial airliners; increased use of aluminum by automobile manfacturers; a drought in the northwest United States where a large share of the nation's aluminum is produced with hydro-electric power; and even the increased production of recycled aluminum which is inappropriate for many DoD systems.

An example of increased commercial demand is provided by the market for integrated circuits. At one time government contracts provided a major impetus for the development and production of integrated circuits. Now with the use of integrated circuits to make automobile ignitions, government purchases have become a relatively small share of one specialized market. The government has encountered difficulty in attempting to have integrated circuits for use in weapons systems produced to more rigorous specifications than required for commercial applications.

Unexpected labor shortages, as those which occurred early in the Vietnam War era, can have a devastating effect on a firm under long term contract. Expensive and time-consuming labor training programs must be undertaken and wages must be raised in order to attract new, even unskilled, workers.

Technological change in some areas, such as electronics, is so rapid that a system could be obsolete if it was produced for five to ten years with no changes. However, even if a long term contract is in force, the cost of any proposed change in design is negotiated in a sole-source environment. Over time, the configuration and cost of a particular system can change significantly. Such changes substantially alter the impact of the original all-or-nothing buy-out competition on system price, and thus make the original investment in competition less worthwhile.

Although the potential for use is limited by all of the problems listed above, long term contracts have been used by MIRCOM of the Army with reasonable success. Modifications may make long term contracts more generally applicable, but perfection should not be expected in markets as dynamic as those for weapon systems. The theory and application of escalation clauses may be improved by more analysis. The government might agree to exclude from long term contracts the cost and delivery quotes of materials known to be in short supply, or with unstable prices. By providing such items as aluminum rods to a contractor as government furnished equipment (GFE), the government would significantly reduce the contractor risk of long term contracts.

Whether such changes can render the long term contracts feasible is, of course, dependent upon the particular circumstances surrounding the competition for each award; but the potential cost and administrative advantage of a long term contract make the effort to improve the applicability worthwhile.

G. INADEQUATE INCENTIVES

While the expected performance improvements and cost savings from introducing competition for reprocurement are substancial

on the average, the incentives to the principals directly involved with the achievement of a particular competitive procurement are often adverse. The program manager is aware of the risks of delay and deterioration of performance and reliability. The original developer-producer would obviously prefer to avoid any loss of revenue. Potential candidates for the competitive award in some situations may refuse to compete because the probability of winning and the expected returns from receiving the competitive award are insufficient to justify the cost of bidding.

The adverse incentives can be mitigated to some extent by the use of more sophisticated techniques than simple competition, and possibly, by changes in procurement, budget, and personnel management policy. There will, however, always be a certain amount of legitimate resistance to the introduction of competition. The resistance, or better, the facts which form the basis of such resistance, will simply preclude the introduction of competition for the procurement of some systems.

The generally poor incentives for achieving sound business management of procurement are discussed in detail by J. Ronald Fox;[1] several apply directly to the decision to introduce competition. The program manager is a military officer who expects to spend only part of his career in that job. The desire for advancement creates sensitivity to the requests and preferences of superiors including those in using commands. Officers in using commands are much more concerned about performance and timely delivery of a system than about the acquisition cost. The expenditure of current funds to realize the future benefits of reduced prices is hard to justify when the officer is a program manager for a relatively short period of time (three years) and the present system for evaluating and rewarding performance

[1] J. Ronald Fox, *Arming America*, Harvard University Press, Cambridge, Mass., 1974.

precludes the pursuit of long term goals. The absence of uniform standards for evaluation of performance encourages conformity to traditional management practices, rather than innovating a risky procedure such as competitive procurement. For all of these reasons the program manager may be understandably reluctant to incur the costs and the risks of delay and performance deficiency for the chance at reduced prices in the future.

Such pressure for achievement of short run versus long run goals, and concern for technical performance of the system versus cost, affects decision makers other than the program manager. It is undoubtedly related to the relatively short run nature of the budgeting cycle, the separation of the acquisition cost of weapon systems from the maintenance and operating budgets of using commands, and the generally difficult task of evaluating performance in a large organization such as the Department of Defense.

Members of Congress, the Office of Management and Budget, officials of the Department of Defense, and others with budget oversight responsibilities tend to heavily discount the future dollar savings expected as a return from the start-up investment. Congressmen are also concerned with the impact of competition on their constituencies, and may view favorably a competition likely to increase employment in their districts but unfavorably one that has the risk of reducing employment. Transcending simple constituency interests is the Congressional view of defense spending as a tool of social and economic policy and the concern that unfettered competition may lead to attrition of the defense industrial base.[1]

The intense interest of Congress and supervisory officials in all aspects of competition can only make the program manager uncomfortable with the idea of undertaking it. If he elects to

[1]Michael D. Rich, *Competition in the Acquisition of Major Weapons Systems: Legislative Prespectives*, R-2058-PR, RAND Corporation, Santa Monica, CA, November 1976.

proceed with competition, he can expect to increase his visibility as a target for criticism of his methodology and his choices and to receive inquiries from superiors or Congressmen, who must be treated with deference and must be responded to with care. Such inquiries might include questions as to why a particular company or its product was excluded or rejected, how dual sourcing can be justified when clearly one firm's price is lower than the other, or a request for proof that the costs of a dual development intended to lead to a production buy-out competition will be offset by production cost savings.

A further deterrent is the general adherence to the assumption that competition is unfeasible for very costly or complex items, primarily because of the cost and difficulty of technology transfer. This assumptive argument is often used when the feasibility of aircraft competition is discussed. It is not answerable on the basis of direct experience, because aircraft have never, to our knowledge, been competitively reprocured. It is known, however, that when an aircraft company is motivated to place a second plant in production (in Europe or Japan, for example), the transfer of technology is found feasible and the costs, presumably, reasonable. Technology transfer has been accomplished by the Navy on one very complex item, the FFG-7 class ship, whose all-up unit cost is of the order of $150 million.

The original developer-producer has an understandable reluctance to assist in the transfer of technology which will result in the reduction of future business. The complexity of the technology and the accompanying technical data package (TDP) make it difficult to distinguish mistakes from deliberate noncompliance. The lack of incentive extends to direct technical assistance supplied to a second source by the original developer-producer. The government must consider such attitudes when techniques for initiating competition are selected. Alternative methods of achieving technology transfer are briefly discussed in Chapter V.

Finally, competent firms may be reluctant to enter the competition for a particular system. Reasons vary with the type of system and the method of competition. For IFB competitions of relatively simple items, larger firms with substantial engineering capability often will not bid. Smaller, so-called loft manufacturers, have lower overhead--partly because of less engineering capability--and can therefore bid lower. They are also accused of buying in (bidding lower than cost) with the intent of "getting well" on engineering change orders. Some of the more established firms will not pursue such a strategy.

For more complex systems, a technical proposal may be required. A firm must have a reasonable chance of winning or be in exceptional need of new business before it is willing to incur the substantial cost of bidding. For that reason, the number of new candidates will be an inverse function of the experience and the perceived quality of performance of the original source.

A second source can expect to incur start-up costs which, because of competitive pressure, may not be directly reimbursed by government contracts for tooling, test equipment, and other pre-production expenses. The expected post-competition production run must be sufficient to amortize any of those fixed expenditures. That simply reinforces the government's own start-up cost problem. The post-competition production run must be sufficient to recover the start-up costs.

The net result of these adverse incentives appears to be resistance to competition where justified only by potential reduction of procurement costs. Competition is more likely to be introduced if the planned production rate is such that a second source is required to maintain or expand the mobilization base. It may also be introduced as a response to demonstrated inadequate performance by the original contractor: costs greater than government estimates; flat progress curves; delivery delays;

and general contractor intransigence. Also, the introduction of competition is sometimes imposed on a system from levels above the project manager in the chain of command. Reasons for such imposition include previous success with related systems; Congressional concern with costs on a highly visible program (the visibility may be due to technical difficulties experienced by the original producer); or to meet DoD quotas for small- and minority-business set asides.

H. NON-PRICE BENEFITS OF COMPETITION

In many cases, price reduction is merely a by-product of the competitive reprocurement of production items rather than the major reason for implementing competition. When a product has been procured and reprocured on a sole-source basis for some time, the contractor may become sanguine about the strength of his bargaining position. He may relax his efforts, transfer capable personnel from the program, or attempt to economize on, say, incoming inspection or quality assurance testing with resulting deterioration of product quality, reliability, or delivery schedules. The contractor may show intransigence when asked to correct material defects, honor warranties, or in negotiating the terms of follow-on contracts. He may submit a torrent of engineering change requests whose principal objective is not product improvement but the raising of the contract price; or he may overprice product improvement changes desired by the government. Instead of negotiating contract disputes or differences in good faith, he may immediately attempt political pressure through members of Congress or acquaintances in the Executive Branch.

Our interviews with personnel in the material acquisition activities of the Services indicate that such symptoms are indicative of a "program in trouble", and that the introduction of actual competition or a credible threat of competition usually has a very salutary impact on the performance and

attitude of the original contractor. Product reliability, quality and delivery show immediate improvement and the contractor becomes more flexible in negotiations. If a competition is actually held, even if the original supplier wins, the product price is substantially reduced from the last sole-source price. Product improvements wanted by the government can be introduced in the technical data package used for competition and will not be unreasonably priced.

Another non-price reason for introducing second-sourcing is simply the inability of any single supplier to produce at required rates without overburdening his own management and administrative capabilities, overloading his production facilities, or overdrawing from the labor pool in his region. In certain cases (shipbuilding and aircraft manufacturing are examples), excess concentration of work at a single facility may cause severe social disruptions in the surrounding community as thousands of workers immigrate into the community and later, when the program ends, become jobless and dependent.

It is important that the potential for such transient impacts be recognized and mitigated. One method is that of split-buy competitions, in which two or more suppliers are awarded fractions of the total buy in inverse relationship to their prices. Maintenance of two producers also reduces the impact on delivery schedules or local strikes or other disruptions to production in a particular plant. Clearly, the direct cost to the government of the split-buy approach will be higher than if the total quantity were awarded to the low bidder. The problem of balancing this incremental cost against the imputed cost to the national welfare of excess geographical concentration of production of a national defense item is beyond the scope of this report.

I. ALTERNATIVES TO PRICE-COMPETITIVE PRODUCTION REPROCUREMENT

Several techniques have been used or are proposed as substitutes for pure price-competitive reprocurement of products identical to those previously procured.

1. Design Competition

The Air Force commonly employs competitive selection of designs for aircraft development and future production. The selection among competing designs is often based on comprehensive technical proposals--paper designs. With the emphasis on "fly-before-buy", a decision to proceed with production procurement may be deferred until several prototypes have been thoroughly tested, but often the development and first production awards are made simultaneously.

The Air Force has recently stated its preference for competitive development, under which two proposed designs are selected for development and prototype fabrication, and proceed to a competitive "fly-off." A single design may be selected at this point, and negotiations for a production contract undertaken with the successful developer. Alternatively, negotiations may proceed for production with both developers, and a decision between them based on both price and design of the system.

Personnel within the Air Force appear to believe that design competition, even when not followed by production competition, yields "carryover" benefits in terms of reduced production prices. We have found no evidence to support this conclusion.

An approach that will produce true price competition involves carrying development to the point where two acceptable designs are available, and then holding a competitive firm-fixed-price buy-out competition covering all anticipated future

production. If such an approach were thought to place too great a burden of financial risk on the contractor, too large and too long-term a financial commitment on the part of the government, or too great a risk of expensive design changes to keep pace with technology, the technique of periodic design-and-price recompetition could be used.

2. Design-and-Price Competition as an Alternate to Pure-Price Competition

Reprocurement of items identical to those previously procured assures that the performance of the item will be standard. Moreover, if the item is a repairable one, spares already in inventory can be used to service it and individuals trained to repair it require no re-education. Thus, presumably, the logistics and support burden is not aggravated.

A serious problem associated with reprocurement is, however, that design changes suggested by technological progress are not being made; as the design ages, the item becomes technically obsolete. Several examples from Air Force experience suggest that efforts to avoid aggravating the logistics burden had exactly the opposite effect. By reprocuring for too long certain "standard" communications and navigation equipments without design change, there were perpetuated in inventory obsolete designs whose reliability, relative to equipments of up-to-date design, became progressively poorer; by the time radically new designs were developed and procured, the equipments of older design had become an enormous maintenance burden.

A second problem of reprocurement is that of technology transfer--the process of providing adequate manufacturing data and drawings from the original producer to subsequent manufacturers to permit fabrication of identical items. Clearly, a second manufacturer's copying and building an item designed and initially produced by a previous manufacturer is almost always more difficult than the second manufacturer's production of an

item of substantially identical performance but of the second manufacturer's design--a design matched to his own manufacturing techniques, processes and facilities.

Thus a potentially worthwhile alternative to competitive reprocurement of identical items on a price basis alone is periodic design *and* price competition. Such competitions are based on form, fit, function specifications that require specific performance characteristics and demand physical, electrical and environmental interchangeability with prior items, but do not require that the internal design of the units be identical with prior internal designs.

The freedom to change internal design permits technological advances to be incorporated, reliability to be improved, and economical changes to be effected. Periodic competitions permit periodic design updating and mitigation of the problem of technical obsolescence, and at the same time have the potential for price reduction.

Because design changes can be expected to cause logistics problems for items subject to organic maintenance, design-and-price competition using form fit function specifications is most clearly applicable to expendables not requiring organic maintenance, such as "wooden-round" missiles, supplier-maintained items such as those under Reliability Improvement Warranty, and items maintained in contractor-operated depots.

It is important to note, however, that the added logistics costs of organic maintenance and spares provisioning for an additional design have not, to our knowledge, been carefully evaluated and analyzed. Thus there is no basis for concluding, *a priori*, that these costs would exceed the benefits in price and technical improvement resulting from design and price competition.

3. The Threat of Competition as a Substitute for Competition

a. Development of a New System as a Competition for the Old

Initiating the development of a new, improved replacement product may be as effective in driving down the price of an older product as competitive reprocurement. If price reduction is the only objective of the new development, the development costs represent an investment whose return is the reduction in old-product costs. A serious difficulty arises if the products are military weapons. If the development leads to a weapon of significantly increased capability, the older weapon may be rendered obsolete and its inventory valueless.

b. Preparation for Competition as a Competitive Threat

A recurring theme among procurement officers is the salutary effect of tangible preparation for competition upon intractable sole-source contractors. Assembling and updating the Technical Data Package is one such tangible step. Visibly budgeting for second-source procurement is another. A third is preparation of an analysis showing the expected cost-reduction benefits of competition as compared with start-up costs.

If these steps prove ineffective in enhancing the government's negotiating position with regard to the sole-source producer's price or schedule, the ground work at least has been laid for further action toward competitive reprocurement: requesting interested potential offerors to submit their qualifications for evaluation, and requesting proposals from qualified suppliers.

J. COMPETITIVE REPROCUREMENT AND DESIGN-TO-COST, DESIGN TO LIFE-CYCLE COST, AND RELIABILITY IMPROVEMENT WARRANTY PROGRAMS

Design-to-cost is a development approach in which a price ceiling for the ultimate production items is established *a priori* as a development goal. Competitive development and a subsequent production competition among the successful developers is as desirable in design-to-cost as in conventional programs. Competition for the production helps assure getting the lowest price, whether or not the ceiling price objective was met by the developers.

The ceiling price goal is, or should be, associated with a specific production quantity to be initially procured. Thus when the need for reprocurement arises after initial production in a design-to-cost program, there is an implication that the required initial quantities were understated and that the ceiling production price goal correspondingly was set too high. However, as we see it, there is no implication that, because the development was design-to-cost, the subsequent production reprocurement should not or cannot usefully be competitive.

Design to life-cycle cost is a development approach in which the goal is to minimize, or to keep below a specified ceiling, the sum of production, operating, maintenance and other variable costs encountered during the life of a product The design ultimately realized may have a higher production cost than alternative designs having the same performance but, because of higher reliability, lower maintenance and hence lower life-cycle costs. Design to life-cycle cost programs should present no additional problems for competitive procurement.

Reliability improvement warranties are now more frequently required for design to life-cycle cost and other combined

development/production programs. The warranties require supplier replacement or repair of units that fail prior to a specified age or specified number of actual operating hours, whichever comes first. The purpose of such warranties is to internalize to the supplier the cost of maintenance in order to encourage designs that achieve a proper balance between performance and reliability and, accordingly, between production and maintenance costs.

When an item previously subject to reliability improvement warranty is to be reprocured, it can not be certain that firms not involved with its design will wish to warrant its reliability. (We know of no such competitive reprocurement.) The item, however, could be competitively reprocured without warranty; and if the procuring agency were to make available reliability history--rates of return, mean time between failure and failure mechanisms--it is quite conceivable that the item could be competively reprocured with warranty.

K. THE NEED FOR FLEXIBILITY

A flexible approach to the application of competition for reprocurement will tend to increase the use of competition by decreasing the problems associated with its introduction and the associated transfer of technology to a new source. Conditions surrounding the procurement of weapon systems vary with respect to the complexity and firmness of the design, adequacy of the TDP, capability of alternative contractors, structure of the particular industry, and capacity of the program office to supervise the competition and the related transfer of technology. Program managers and contract officers familiar with the conditions surrounding the procurement of a particular system will, correctly, resist the introduction of competition if they deem it inappropriate or if the inappropriate technique is imposed.

There are several techniques available for the introduction of competition which reflect the varying degrees of complexity of different systems. Yet there is a definite bias against using the more sophisticated techniques. Defense Acquisition Regulations (DARs, formerly ASPRs) fail to encourage pure price competition by means other than formal advertising, either regular or two-step. Yet many defense systems and equipments for which price competition is warranted are far too complex and inadequately specified to permit their procurement by formally advertised invitation for bid (IFB) followed by firm fixed-price (FFP) award, or are too critical to the national defense to warrant the risks of delays and defaults by contractors who may be classed as "responsible" under IFB selection criteria, but are unqualified technically.

The Armed Services Procurement Regulations (ASPRs) provide 17 exceptions to the use of IFB competition. Not one of the exceptions explicitly recognizes the introduction of a second source in order to reduce price through subsequent competition as a justifiable reason for using negotiated competition. Thus program managers whose objective is securing price competition by some technique other than IFB resort to the subterfuge of applying for a Determination and Finding (D&F) by appropriate authority that contract negotiation to develop a second source is necessary "to keep facilities available in the interest of national defense for industrial mobilization" (Exception 16 of ASPR), or those other permissible exceptions to which the requirement for IFB procurement apply. The procedure for obtaining a D&F is rigorous and time consuming, and accordingly can be expected to act as a deterrent to initiating competition on equipment and systems that are too complex for procurement by formal advertising.

Pursuit of goals other than reduction of system price can impact the use of competition. The desire to use the procurement

budget as an instrument of social policy leads to the break-out of subcomponents for small and minority-owred businesses. Such break-outs for competition, even when not set aside specifically for small and minority-owned businesses, are often regarded as inappropriate and especially risky applications of IFB competition by personnel of materiel commands. Bad experiences resulting from the imposition of IFB competition, and inadequate funding and personnel staffing, reinforce a negative attitude of some personnel with respect to competition.

Relaxation of procurement regulations in order to permit greater flexibility by encouraging the use of various techniques of securing price competition appears to be desirable. Impediments to the use of more sophisticated techniques could also be overcome by more flexible funding and personnel staffing. The various techniques for introducing competition are discussed briefly in the main body of this report. A list, by no means comprehensive, of policy changes to improve the use of competition is also presented therein.

APPENDIX H

REVIEW OF APRO AND TECOLOTE REPORTS

REVIEW OF APRO AND TECOLOTE REPORTS

In a three volume study, the Army Procurement Research Office, with the assistance of Tecolote Research Inc , intensively analyzed the costs of eighteen weapon systems which had previously been chosen for competitive reprocurement. A methodology was developed to systematically estimate the savings for each system resulting from the introduction of competition. A forecasted savings methodology (FSM) was then proposed as an aid to selecting systems for competition. The FSM consists of a forecasting screen which offers a list of conditions to be met before a system can be considered for competition; a forecasting equation for actual unit price after the competitive buy-out; and a competition index which incorporates information on qualitative factors that influence the benefits of introducing competition. The same order of presentation will be followed in this review of the APRO study.

A. THE ESTIMATED SAVINGS METHODOLOGY AND ANALYSIS OF SYSTEMS

Although the methodology employed by APRO for estimating the savings which result from competition is generally sound, there are questions of judgment in the application of the methodology and in the interpretation of the results. The basis of most of the problems is simply inadequate data, but they are occasionally compounded by inconsistent application and documentation of the methodology. The topics addressed in this section are the proper method of expressing savings; inappropriate estimation of progress curves; and pursuit of objectives other than cost reduction which can reduce the estimates of savings attributed to competition.

1. The Savings Calculation

The incomplete information on the fixed costs incurred to introduce competition precludes the estimation of an internal rate of return for each system and also makes the APRO percentage savings figures incomparable between systems. By expressing savings as a percentage of total program costs rather than as a percentage of projected post-competition production costs, the APRO method understates the percent savings on future production costs which are to be expected from the introduction of competition. The APRO method of calculating percent savings is also unduly sensitive to the relative length of the pre-competition production run. For these reasons it is useful to express savings in terms of recurring production costs for post-competition production only and then compare those savings with the fixed costs of introducing competition if and when these costs are available.

To clarify the suggested adjustments, the savings, as estimated by APRO in absolute terms (SAV1) and in percentage terms (PCSAV1), are represented by the following formulas:

$$AC = SSC1 + SSC2 + SBC1 + SBC2 + PCC + NRC$$

$$EC = SSC1 + SSPC + NRC$$

$$SAV1 = EC - AC - FC$$

$$PCSAV1 = \frac{SAV1}{EC} \times 100$$

where

AC = Actual costs

EC = Estimated costs

SSC1 = The cost of the precompetition sole source contracts of the original supplier

SSC2 = The cost of the precompetition sole source contracts of suppliers other than the original

SBC1 = The cost of the share of the split-buy contracts awarded to the original supplier

SBC2 = The cost of the share of the split-buy contracts awarded to the other suppliers

PCC = The cost of the competitive buy-out and all follow-on contracts

NRC = Any post-competition, non-recurring costs incurred

FC = Costs incurred by the government solely because of implementing competition

SSPC = The estimate of the sum of the costs SSC2, SBC1, SBC2, and PCC, if those contracts had been awarded to the original source without the threat of competition.

We suggest two alternative measures of savings. First:

SAV2 = EPCC - PCC

PCSAV2 = (SAV2/EPCC) x 100

where

EPCC = The estimate of PCC, the cost of the competitive buy-out and all follow-on contracts if those contracts had been awarded to the original source without the threat of competition.

The second alternative is:

SAV3 = (EC - SSC1 - NRC) - (AC - SSC1 - NRC)

PCSAV3 = (SAV3/(EC - SSC1 - NRC)) x 100.

The exclusion of NRC and FC is suggested because the estimates of those costs are not consistent from one system to the next due to incomplete data. It seems preferable to obtain a cleaner estimate of recurring production costs which can be compared between systems, and compared with fixed cost as they become available.

Decisions regarding when to introduce co-production, split-buy competition, and competitive buy-outs, and the relative length of those production runs are influenced by factors other than the desire to minimize system acquisition costs. (This is discussed more fully below.) Frequently the length of the original producer's sole source production run, the educational buys for the second source and the number of split-buy competitions

are longer than required for second source experience. Such extensions will generally result in greater costs than necessary and in particular will impact a downward bias to the estimates of percentage savings.

While the PCSAV2 estimate excludes all but the costs of the post-competitive buy-out production, PCSAV3 excludes only the original producer's sole source production cost and the non-recurring costs. PCSAV3 was created partly for convenience and partly because split-buy competition can result in lower, if not the lowest, cost. Cost estimates of post-competitive buy-out production are sensitive to how far out on the progress curve such production would have taken place. That is, what volume is assumed to have been produced by the sole source before the buy-out? In particular, the volume of the split-buy production contracts and the educational buys from the second producer are treated as if they were produced by the original supplier when the cost of the post-competitive buy-out production run is projected. Thus, the length of the pre-competitive buy-out production runs inevitably influences the estimates of savings whether the measure SAV2 or the measure SAV3 is used.

2. Estimation of Progress Curve

A log-linear progress curve, fitted to the production experience of the original supplier, is used to project what the post-competition production costs would have been without the introduction of competition. Such projections are required for computation of the savings estimates. The general problems with this methodology have been discussed elsewhere; here we will limit comments to particular problems of applying the methodology to the weapon systems analyzed.

The first and foremost problem is simply the lack of sufficient reliable data. According to the APRO reports, cost and quantity data are often reported in a form which requires

considerable adjustments before a progress curve can be estimated. However, the adjustments are not documented in a form which allows validation; the adjustments of the authors must be accepted in order to proceed with the analysis.

Production lots rather than the individual units produced serve as the observations for purposes of estimation. Production lots sometimes correspond to one contract; other times a contract might include more than one production lot. The documentation does not always indicate which situation prevails.

Theoretically, the progress curve should be fit to observations generated under sole source contracts awarded to the original supplier (usually the system developer). The observations should be representative of the experience which would have prevailed if the system had not been selected for the introduction of price competition. In particular, the contracts should not be negotiated under the pressure of actual or imminent price competition for the contracts. In practice this turns out to be a severe constraint. Very few observations, representing a small percentage of the total volume produced, are available for estimation. To carry out the analysis of some systems, supplementary information was required or the implicit methodological assumptions were violated.

Progress curves for ten of the eighteen systems analyzed were based on something other than sole source production lots. For the TOW missile, a 90 percent progress curve was assumed for the material and subcontracting unit costs. The Dragon round and Dragon Tracker progress curves were based on cost estimate studies. Split-buy awards were used as data points in the estimation of the progress curves of both the main assembly of the Mark-46 torpedo and for the Sidewinder AIM-9B missile. Progress curve slopes were assumed for the SHRIKE missile, FAAR Radar, FAAR TADDS, and the PP-4763/GRC. The slope of the AN/UPM-98 progress curve is based on historical averages for electronics.

Use of split-buy data points to estimate the sole source progress curve clearly violates the methodological assumptions. Rather than reduce the number of systems available for analysis it may be preferable to use progress curve slopes based on historical averages for the particular system at hand. Such assumptions should be clearly documented in summary tables as well as in the description of the analysis. Because of the sensitivity of the savings estimates to the progress curve slopes, it might also be useful to provide a list of savings estimates corresponding to alternative assumed progress curves.

3. Evidence of Multiple Goals

The qualitative comments which support and elaborate on the empirical analysis of the systems suggest that the government might have simultaneously pursued goals other than cost minimization with the introduction of competitive bidding for source selection. This possibility is suggested in the selection of systems for the introduction of competition, the selection of the new supplier, and the length of the educational buy for the qualification of the second source. To attribute the extra costs to the introduction of competition would be misleading.

a. System Selection

Without the benefit of a set of standards by which systems could be optimally selected, it is to be expected that the services would occasionally select a system for competitive reprocurement which *ex post* is revealed not to benefit from price competition. The purpose of this section is not to criticize decisions which might have appeared reasonable *ex ante* or made for reasons other than expected reductions in procurement costs; rather, the analysis is directed at understanding why competition does not reduce system costs in particular situations and also to develop criteria for selecting systems for competition.

The Standard Missile is an example of a weapon system whose costs were not reduced as a result of competitive bidding. In fact, the original producer, General Dynamics, won the competitive buy-out. Further, the actual post-competition recurring production costs were greater than the estimated costs as projected by the sole-source progress curve. While competition might result in a loss because of the various fixed costs associated with its implementation, it is difficult to accept the implication that variable production costs of the same supplier were higher than they would have been without the introduction of competition. We are forced to look elsewhere for an explanation. Either the progress curve is underestimating future costs or some other change in conditions increased actual costs.

The qualitative comments included with the analysis of the Standard Missile system tell us that a labor strike created some problems, but a greater factor may have been the termination of the Standard ARM production during the period of the competitive buy contract. To quote the report:

> The Standard ARM production contracts were awarded to General Dynamics concurrent with Standard Missile. The ARM program was awarded during the Viet Nam action and was a high-urgency program. For this reason, it was considered to be relatively generously funded by some Navy personnel and because of the high degree of commonality between early configurations of the Standard ARM and Standard Missile, it was felt that the ARM program may have subsidized the Standard Missile program to some extent.[1]

Thus, as verified *ex post*, the Standard Missile was not a good candidate for competition. Experience with the Standard Missile suggests that the possibility of economics of joint production and of cross subsidies between systems should be one

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[1] Arthur J. Kluge and Richard B. Liebermann, *"Analysis of Competitive Procurement,"* Tecolote Research, Inc., TM-93, August 1978, p. 15.

of the criteria carefully analyzed before the selection of a system for competitive procurement.

Another reason for competitive procurement is discontent with the quality of the product delivered by the original source. That appears to be the case with the Walleye Missile which was broken out for competition relatively late in the production run and as a result showed a loss from competition.

Similarly, the AIM9B was broken out for a series of competitive split-buys followed by a competitive buy-out which was won by the second source. After a production break of almost five years, the government returned to the original producer for the last two contracts. No reason for the move is reported, but it is unlikely to have resulted in lower production costs. Again the pursuit of some other goal resulted in a reduction of the cost savings attributed to competition.

b. Selection of Second Source

Selection of the proper second source is at least as important as the selection of the weapon system for successful competitive reprocurement. Low bid should not be the only criteria for awarding the competitive contract. There should be some evidence that the contractor has the capability to deliver a product of adequate quality and reliability, and that it can make the delivery on time.

Several of the contractors selected by competitive bid eventually defaulted on their contracts. In at least one case, while the bid of the second source was substantially below that of the original supplier, the second source had no experience with anything as complicated as the system for which it was competing. Another firm known to have narrowly escaped bankruptcy proceedings was awarded a competitive contract, but defaulted when it was forced into bankruptcy.

For the PP-4763/GRC, part of the competitive buy was set aside for award to small businesses as required by law. In some cases the small businesses require extra financial support in order to deliver the product, are late with delivery, and some default.

The awarding of contracts to inexperienced firms might be desirable in order to expand the defense supply production base, or to assist the development of small and minority-owned businesses. It is not, however, the most likely way to successfully reduce the cost of weapon system procurement. Competitive reprocurement inevitably involves extra risk of contract default, delays or cost overruns. Those risks should generally be reduced by selecting a second source with better capability even at the cost of accepting a higher price bid. The tradeoff between risk and price may be difficult to evaluate during contract negotiations and mistakes are to be expected. However, some of the problems with second sources recorded in the analysis of the systems could have been avoided. To attribute the extra costs associated with such contract problems to competition is misleading and understates the benefits to be expected from a well managed program of competitive source selection.

c. Excessive Learning Buys and Split Buys

A major cost of competitive procurement is frequently the cost of transferring technology from the original producer-developer to the second source. Partly because the use of licensing agreements and other aids to technology transfer are not well developed in the weapon system acquisition process, learning buys are awarded to the second producer on a sole-source basis before competitive bidding is initiated. While the complexity of some systems dictates that a firm acquire some production experience before it can submit a reasonable bid, the volume of some of the second source pre-competition production runs seems excessive.

Related to the excessive length of pre-competition second source production runs are the use of split-buy competitions. With split-buy competitions, the lowest bidder receives the larger share of the contract and the high bid firm receives the remainder. In some systems the split-buy contracts are eventually followed by a competitive buy-out where the winner is awarded the total contract and recieves the follow-on contracts as well. In at least one system, split-buys were the only form of price competition because no buy-out occurred.

Split-buys appear to be used, at least partly, to provide experience to a second source before the winner-take-all buy-out. They also have the appeal of apparent competition for the largest share of each production contract. However, they can result in higher production costs than would occur if one firm produced the total volume. To use a simple example: two firms have exactly the same progress curves, and the slope of the curves is 85 percent. If each firm produces exactly half of the total volume, then total costs will be 15 percent greater than if one firm produced the total and thereby moved further out on the progress curve.

Again, extended pre-competition sole source runs for the second source and the split-buy competition, may have other justifications. However, the extra costs associated with such methods should be attributed to the achievement of those goals; they should not be charged in total as costs of introducing competitive reprocurement.

B. THE FORECASTED SAVINGS METHODOLOGY

The introduction of competition is analogous to an investment. With the expectation of future returns in the form of decreased procurement prices, substantial costs are incurred in order to initiate competition. Whether such an investment is worthwhile cannot be known *a priori*. As with private

commercial investments, however, the government would be well served by accurate forecasts of expected future returns from introducing competition to various weapon systems.

In the reports APRO-709-1 and APRO-709-2, a three part forecasted savings methodology (FSM) is proposed. It consists of a competition screen, a forecast of expected savings, and a competition index. While each part of the FSM is potentially helpful, the usefulness of each part may be overstated and it might not be operational in the present form. The problems of each part of the FSM will be discussed in turn.

1. The Competition Screen

According to the APRO report, the competition screen is a list of criteria that must be met in order to consider competition. The list is reproduced as Table H-1.

Table H-1. FACTORS INFLUENCING COMPETITION: THE COMPETITION SCREEN

1.	Prohibitively High Initial Start-up Costs
2.	Lack of a Definitive Technical Data Package or a "Soft" Technical Data Package
3.	Proprietary Data--Technology Transfer
4.	Congressional Interests--Budget Constraints
5.	Inadequate Production Quantities
6.	Economic Climate
7.	Length of Planned Production Cycle
8.	Critical or Scarce Materials
9.	Non-Conformance to Cost Accounting Standards
10.	Special Tooling/Test Equipment
11.	Testing Requirements
12.	Government/Industry Wide Case Flow Problems

The competition screen lists several, if not all, of the factors which influence the expected return to an investment in competition. For some systems, the costs of such things as acquiring an adequate technical data package or proprietary data might be sufficiently expensive to more than cancel any reasonable forecast of savings in production costs. In general, though, it is a mistake to regard each of the criteria as a separate hurdle which must be passed before competition can be introduced successfully. On the contrary, each criterion is a matter of degree in its influence on expected returns from an investment in competition and they are highly interdependent. For example, whether initial production costs are prohibitively high (criterion 1) depends upon the other costs of introducing competition (e.g., 2, 3, 8, 9, 10, and 11) versus the expected future savings in production costs.

For a characteristic to be a useful decision criterion, it must be observable during the planning period before competition is introduced, and it must be feasible to make an estimate of its impact on costs or benefits. At present there is no sufficient data base to develop standard formulas which would relate identifiable characteristics of a weapon system and its production environment to an expected level of cost for each of the screen criteria. Therefore, such estimates will necessarily be subjective.

Unfortunately, some of the criteria listed in the competition screen may not be easily observable, nor is their impact estimable before the system is put out for competition. Criteria 2,6,8, 9 and 12 could all be unobservable before competition is introduced. The same problem holds for some items in the index of competition discussed below.

2. Forecasting Methodology

The second step of the FSM for any candidate system which passes the competition screen is an estimate of savings. The logic of the forecasting methodology parallels the savings methodology used to estimate the savings of each system analyzed in the reports. The difference is that a forecast of the post competition actual unit price is required in order to derive the forecast of savings for a system which has not been submitted for competitive reprocurement.

Data from 16 systems, whose actual savings from competitive procurement were estimated in the APRO and Tecolote reports, were used to estimate a forecasting equation of the following form:

$$AUP = PUP^{.975}\, ROQ^{-.157} \qquad R^2 = .9994$$

where

AUP = the actual unit price for all production which occurred after the competitive buy-out

PUP = the unit price projected by the sole source progress curve over the post-competitive buy-out production

ROQ = the ratio of post-competitive buy-out production to total program production quantity.

The coefficient of determination of the regression equation appears to imply that savings can be estimated with remarkable precision. With knowledge of only the projected unit price, which is based exclusively on pre-competition experience, and the ratio of the post-competition quantity to the total program quantity, that is indeed surprising.

A closer look at the equation suggests that the implication is misleading. First, the estimated equation might not hold for the population of all systems which are candidates for competition. The equation is estimated with data from only sixteen

systems, all of which were competed for one reason or another, and they are not necessarily a representative sample of all systems which might be considered for competition.

Second, the unit prices (recorded on page 18 of APRO-709-2) used to estimate the equation are presumably derived from the costs and projections recorded with the estimation of the savings for each of the systems. However, we could not verify the derivations of AUP and PUP for five of the sixteen systems. Unreported adjustments to the prices appear to have been made. Further, the SHRIKE Missile was assigned a value of one for ROQ. That implies that the total production occurred after a winner-take-all competitive buy-out. However, there was no competitive buy-out for the SHRIKE Missile program. On the contrary, it was produced under a continuous series of split-buy awards; ROQ should equal zero for the SHRIKE Missile.

That brings us to another point. For some systems, the SHRIKE Missile in particular, the earlier analysis attributed considerable savings to split-buy competition. The forecasting equation does not provide a means of estimating such savings.

The remaining criticisms are of a more technical econometric nature. The APRO equation is estimated by suppressing the intercept. That results in the moments being calculated about the origin rather than the mean, without a resulting overstatement of the coefficient of determination (R^2). For this particular equation the overstatement is rather small.

The problem of specification of the forecasting equation is analogous to forecasting the gross national product (GNP). If the error in forecast is expressed as a percent of actual GNP, then use of this period's GNP as a forecast of next period's GNP results in a rather small percent error. However, the real interest is in the difference in levels or, equivalently, the rate of growth in GNP between the two periods. If

the error of the forecasted difference (or growth rate) is expressed as a percentage of the actual difference (or growth rate), the apparent precision is reduced.

For the sixteen systems used to estimate the regression equation, the difference between AUP and PUP for each system (although substantial in percentage terms) is dominated by the larger differences in unit prices between systems. As a result, the simple correlation of 0.96 between AUP and PUP is high and suggests the usefulness of PUP as a forecast of AUP. However, the correlation of PUP with the percentage reduction in unit costs $\left(\frac{PUP - AUP}{PUP}\right)$ is only 0.25, a less encouraging number. Another example of this point is provided by a comparison of different forms of the APRO forecasting equation. Re-estimating the equation in linear rather than log-linear form gives the following parameters, with t-statistics given in parentheses:

$$AUP = 1946.74 + \underset{(12.845)}{0.635}\ PUP + \underset{(.187)}{1348.54}\ ROQ \quad R^2 = .9277 \qquad (2)$$

Regressing savings per unit (SAV = PUP - AUP) on the independent variables results in the following equation:

$$SAV = -1946.74 + \underset{(7.380)}{0.365}\ PUP - \underset{(-0.187)}{1348.54}\ ROQ \quad R^2 = 0.8015 \qquad (3)$$

As expected, the coefficient of determination for equation 3 is less than that of the equation which forecasts the unit price, 0.9277.

Because the forecasting equation was estimated in a log-linear form, a comparably simple transformation to unit cost savings cannot be made. However, the log of the ratio AUP/PUP can be regressed on the logs of the independent variables with the resulting estimates:

$$\log\left(\frac{AUP}{PUP}\right) = -0.181 - \underset{(-0.123)}{0.006}\ \log(PUP) - \underset{(-1.385)}{0.167}\ \log(ROQ) \qquad R^2 = .1308$$

Taking the antilog of the dependent variable and subtracting it from the constant "1" provides an estimate of percentage savings:

$$1 - \frac{AUP}{PUP} = \frac{PUP - AUP}{PUP} .$$

Thus, the percentage savings on recurring production costs are estimated with an even lower coefficient of determination. That simply reflects the fact that the relative impact on variance of the residuals of systems with a large unit price is reduced as we move from equations for unit price to equations for percentage savings.

In conclusion, the two explanatory variables, projected price and ratio of post-competition quantity to total program quantity, are insufficient to accurately predict the actual savings from introducing competition. That is not surprising; an accurate forecast of savings derived from an explicit model requires information on the post-competition progress curve as well as the pre-competition learning curve. Such information is not availalbe *ex anti* for use as a forecasting tool, rather it must also be forecasted.

Perhaps with a larger, more representative, and more extensive data base improved, though certainly not perfect, forecasts of savings will be possible. They will require a better understanding of the relation between characteristics of the system, of the original producer, and of the potential competitors with realized savings than is summarized in the forecasting equation proposed in the APRO reports.

3. The Competition Index

The APRO report recognizes the need to supplement the forecasting equation estimate of savings with more information on qualitative factors which could influence the amount of savings

realized when competition is introduced. It was proposed that the eight qualitative factors listed in Table H-2 be summarized in a competition index for each system as a measure of the impact on the competitive environment. Each factor is assigned a score in the range from +10 if the factor has an "Extremely Strong Increasing Influence" on the benefits to competition to -10 if the factor has an "Extremely Strong Decreasing Influence." A weighted average of the individual scores provides the value of the index for one system.

The weights are normalized and sum to one for each system. The description of the index suggests that the relative weight assigned to each factor might vary from system to system. Such changes are to reflect differences in the relative importance of the factors between systems; the result is an index which is difficult to interpret.

The subjective assignment of values to the factors is useful if it can be done consistently from one system to the next. The major problem is, as with the competition screen, one of operability of the index. The index is not useful unless a reasonable value can be assigned to each factor before competition is introduced. Some of the factors such as "Perception of Competitive Position" and "Company Goals" might be revealed to government decision makers indirectly and only as competitive bids are submitted.

The actual impact of each factor, and the index as a whole on savings, in unknown; that fact obviously affects its usefulness. As part of the upgrading of the forecasted savings methodology, the impact of the qualitative factors could be evaluated including their scores or an index of their scores among the independent variables in the forecasting equation. That would allow the simultaneous determination of the influence of the quantitative and qualitative factors on savings and ultimately enable forecasts which combine both types of information

Table H-2. COMPETITION INDEX

1. Perception of Competitive Position
   a. Production experience
   b. Capacity
   c. Age of facilities
   d. Area wage rates
   e. Union
2. Anticipated Future Requirements
   a. United States
   b. Foreign Military Sales
   c. Spinoffs
   d. Other components
3. Economic Conditions
   a. Current
   b. Future
4. Company Goals
   a. Immediate
   b. Long-range
5. Risk Assumption
   a. Technical risk
   b. Quality of Technical Data Package
6. Capital Investment
   a. Dollar value required
   b. Use of Government Furnished Equipment
   c. Type of equipment
7. Make or Buy Considerations
   a. Sole-source subcontractors
   b. Government-directed subcontractors
8. Other
   a. Types of contracts
   b. Should cost
   c. Value engineering

C. SUMMARY

In summary, the overall FSM proposed by APRO moves in the right direction but is insufficient. The competition screen and competition index should concentrate on factors which are observable *a priori*. While several intuitively appealing factors are listed, further research is required to determine what characteristics of systems, markets, and contractors have a significant impact on realized savings from competition. Assessment of the adequacy and even the necessity of the technical data package might be improved and better estimates of the cost of technology transfer developed with further analysis.

Subjective assessment of qualitative data is inevitable in the selection of systems for the introduction of competition. Analysis and assignment of values to factors should be applied as consistently as possible across systems.

Because insufficient data preclude the development of standardized formulas, the logic used must be clear and consistent. What data are available should be used to best advantage. As pointed out above, the regression equation overstates the precision with which savings can be estimated. Use of qualitative variables--even though their values are assigned subjectively--in the regression equation, could improve the reliability of savings forecasts. When and if that is possible, it would provide a better method of combining qualitative and quantitative information for forecasts.

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APPENDIX 1

DESCRIPTION OF DATA BASES

DESCRIPTION OF DATA BASES

A. ARMY PROCUREMENT RESEARCH OFFICE (APRO) 1977

Sixteen items comprised the data base for the APRO study. Six of these were analyzed by Tecolote Research, Incorporated in Report TM-93; the remainder were analyzed by APRO in Reports 709-1 and 709-2. The data were acquired from contract files, cost reports, progress briefings, technical data packages, pertinent studies, and interviews with government and contractor personnel. Contract numbers are given where available, and reports and studies are cited when they are the source of the data. Brief descriptions of the systems and their production histories are also given.

Although the data sources are well documented, it is difficult to validate many of the results because the adjustments and manipulations of the data are very poorly documented. The learning curves were based on recurring costs only, but it is not clear how these were separated from non-recurring costs. In several cases the data are "adjusted" to fit assumed learning curves; e.g., the TOW Subcontracts, FAAR Radar, FAAR TADDS, and SHRIKE Missiles. Other problems include learning curves based on split-buy observations (Sidewinder AIM 9B, Mark 46 Torpedo), savings calculated where all contracts were sole source (AN/ARC-31), and a learning curve projection which could not be verified (Shillelagh Missile).

Over half of the items studied are missile systems and subsystems. The first-unit costs of the sole source learning curves range from $3,532 to $530,226 with an average of $81,063 (1972$). None of the systems were procured by the Air Force; the Army and

Navy each produced eight items. The total quantity procured averaged 53,419 units, ranging from 175 to 152,455. Table I-1 gives the details.

B. INSTITUTE FOR DEFENSE ANALYSES (1974)

Nineteen systems and subsystems were used in the quantitative analysis of the earlier IDA study. Most of these are either missile subsystems or electronic communications devices. Fourteen other items were examined but were not suitable for the analysis because of a lack of data, extensive engineering changes, or claims against the government. A brief description of each system is given along with the actual data used in the analysis. The total number of units procured of each system varies from 666 to 125,471, with an average of 22,395. Program duration averaged 5.3 years, ranging from three to nine years. Most of the systems were procured by the Army, some by the Navy, but none by the Air Force. The computed sole source learning curves had an average first-unit cost of $126,825 (1970 dollars), with a very large range from $2,678 (FGC-20 Teletype Set) up to $1,200,370 for the TALOS Guidance and Control Unit. The details are given in Table I-2.

C. ARMY ELECTRONICS COMMAND (1972)

Twenty-two Army-procured electronics items were used in the U.S. Army Electronics Command (ECOM) study. Contract numbers, years, number of units procured (sole source and competitively), and prices are given. Information on lead time and delivery schedules was available from contract files for 13 of the items. These comprise the data sample for the regression analysis done in the study. The total number of units procured for all 22 items ranges from 87 to 57,860, averaging at 8,767. Program duration averaged 3.5 years, ranging from one to six years, and the average sole source unit price for all items was $3,075 (1972 dollars). The details are given in Table I-3.

Table I-1. APRO DATA BASE

Item	Number of Sole Source Units	Size of First Competitive Buy	Calculated Sole Source First-Unit Cost (1972$)	Sole Source Progress Curve Exponent	Unit Cost, First Competitive Buy (1972$)
1. TOW Missile	[3]	[3]	49,223	-.201 est. avg.	[3]
2. TOW Launcher	[3]	[3]	62,260	-.105 avg.	[3]
3. DRAGON Round	[3]	[3]	21,815	-.234	[3]
4. DRAGON Tracker	[3]	[3]	44,503	-.189	[3]
5. SHILLELAGH	17,945	29,385	32,266	-.233	3,104
6. FAAR Radar	[3]	[3]	315,565	-.184 est.	[3]
7. FAAR TADDS	[3]	[3]	10,384	-.184 est.	[3]
8. PRC-77	19,635	4,925	3,891	-.137	724
9. ARC-131	7,232	657	3,532	-.022	3,335
10. UPM-98	501	124	43,150	-.234 est.	8,676
11. SHRIKE	103[1]	588[1]	15,171	-.136 est.	2,504[1]
12. SIDEWINDER AIM -9B	272	3,467	45,849	-.294	5,190
13. SIDEWINDER AIM-9D/G	425	1,775	15,352	-.098	6,424
14. Standard Missile	960	1,087	530,226	-.321	58,096
15. BULLPUP	10,895	1,278	101,619	-.310	4,598
16. MARK 46	1,750[2]	100[2]	286,209	-.260 avg.	38,899[2]

Note: est. - Estimated; avg. - Weighted Average

[1] Dash 1 G & C Only

[2] Main Assembly Only

[3] This information is classified, and therefore, is not contained in this paper.

Table I-2. 1974 IDA DATA BASE

Item	Number of Sole Source Units	Size of First Competitive Buy	Calculated Sole Source First-Unit Cost (1970$)	Sole Source Progress Curve Exponent	Unit Cost, First Competitive Buy (1970$)
1. BULLPUP (Martin)	10,195	1,078	121,850	-.349	3,725
2. TALOS G&C Unit	1,605	47[illegible]	1,200,370	-.276	87,636
3. TD-660 Multi-plexer	2,175	425	239,167	-.496	3,524
4. TD-352 Multi-plexer	1,383	2,218	16,497	-.062	4,291
5. TD-202 Radio Combiner	827	2,185	19,680	-.194	1 741
6. TD-204 Cable Combiner	2,687	5,943	31,668	-.246	1,877
7. HAWK MMMP	8,128	2,346	5[illegible],161	-.432	1,014
8. APX-72 Airborne Transponder	13,250	3,373	66,37[illegible]	-.344	1,653
9. MK-48 Warhead	552	480	34,000	-.171	5,087
10. MK-48 Electrical Assembly	617	417	17,601	-.3[illegible]1	6,027
11. Aerno 60-6402	535	39	10,520	-.065	3,030
12. SPA 25 Radar Indi-cator	1,631	323	271,5[illegible]	-.460	6,819
13. SHILLELAGH Mis-sile	1,393	2[illegible],512	15[illegible],622	-.396	3,041
14. ROCKEYE Bomb	35,855	3[illegible],087	32,770	-.262	1,641

Table I-2 (cont'd)

Item	Number of Sole Source Units	Size of First Competitive Buy	Calculated Sole Source First Unit Cost (1970$)	Sole Source Progress Curve Exponent	Unit Cost, First Competitive Buy (1970$)
15. TOW Missile	24,750	12,000	15,540	.134	1,999
16. USM-181 Telephone Test Set	842	357	4,751	-.285	422
17. FGC-20 Teletype Set	1,704	276	2,678	-.044	1,308
18 MD-522 Modulator-Demodulator	2,542	697	18,480	-.219	1,275
19. CV-1548 Signal Converter	3,945	7,638	37,414	-.274	1,503

Table I-3. ECOM DATA BASE

Item	Number of Sole Source Units	Size of First Competitive Buy	Average Sole Source Unit Cost (1972$)	Unit Cost, First Competitive Buy (1972$)
1. AN/ARC-54	8,966	4,500	5,343	1,780
2. AN/PRT-4 Squad Radio	5,529	28,809	355	205
3. TD-352	1,383	1,770	11,450	4,458
4. TD-202	687	1,955	6,614	2,386
5. TD-204	2,687	5,943	6,170	1,951
6. TD-660	2,175	425	10,855	3,800
7. MD-522A/GRC	2,542	697	4,463	1,390
8. AN/ARC-131	897	614	3,243	2,324
9. AN/UPM-98	130	79	10,279	5,615
10. PP-4763( )/ GRC	1,818	635	1,273	503
11. MK-980 ( )/ PPS-5	65	22	10,344	4,053
12. AN/APM-123	1,135	242	6,340	2,340
13. AN/GRC-103	750	142	30,886	11,253
14. AN/GRC-606	2,390	4,703	21,138	8,300
15. AN/PRC-77	18,337	39,523	1,275	560
16. AN/PRC-25	8,248	7,644	3,149	1,180
17. S-250 Shelter	340	283	4,604	2,057
18. AN/FYC-8X	100	47	15,731	8,095
19. CV-1548	3,945	295	5,513	1,621
20. AN/ASN-43	1,404	872	2,474	2,027
21. AN/FLR-9	--	--	--	--